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Toxicological Benchmarks for Wildlife

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TABLES

ACRONYMS and ABBREVIATIONS

BAF	Bioaccumulation Factor
BCF	Bioconcentration Factor
bw	Body Weight
DOE	United States Department of Energy
EPA	United States Environmental Protection Agency
FCM	Food Chain Multiplier
FEL	Frank Effects Level
LD_{50}	Lethal Dose to 50 percent of the population
LOAEL	Lowest Observed Adverse Effects Level
NOAEL	No Observed Adverse Effects Level
P_{oct}	Octanol/Water Partition Coefficient
PCB	Polychlorinated Biphenyl
RfD	Reference Dose
RTECS	Registry of Toxic Effects of Chemical Substances
TCDD	Tetrachlorodibenzodioxin
TCDF	Tetrachlorodibenzofuran
TWA	Time Weighted Average

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1. INTRODUCTION

The process by which the ecological risks of environmental contaminants is evaluated is two-tiered. In the first tier, a screening assessment is performed where concentrations of contaminants in the environment are compared to toxicological benchmarks. These benchmarks represent concentrations of chemicals in environmental media (water, sediment, soil, food, etc.) that are presumed to be nonhazardous to the biota. While exceedance of these benchmarks does not indicate any particular level or type of risk, concentrations below the benchmarks should not result in significant effects. In practice, when contaminant concentrations in food or water resources are less than these toxicological benchmarks, these contaminants may be excluded from further consideration. If, however, the concentration of a contaminant exceeds a benchmark, the contaminant should be retained as a contaminant of concern (COC) and be subject to further investigation.

Toxicological benchmarks may also be used as part of a weight-of-evidence approach (Suter, 1992) in a baseline ecological risk assessment, the second tier in ecological risk assessment. Under this approach, toxicological benchmarks are one of several lines of evidence used to support or refute the presence of ecological effects. Other sources of evidence include media toxicity tests, surveys of biota (abundance and diversity), measures of contaminant body burdens, and biomarkers.

This report presents toxicological benchmarks for assessment of effects of 55 chemicals on six representative mammalian wildlife species (short-tailed shrew, white-footed mouse, cottontail rabbit, mink, red fox, and whitetail deer) and eight avian wildlife species (American robin, woodcock, wild turkey, belted kingfisher, great blue heron, barred owl, Cooper's hawk, and red-tailed hawk) (scientific names are presented in Appendix C). These species were chosen because they are widely distributed and provide a representative range of body sizes and diets. The chemicals are some of those that occur at United States Department of Energy (DOE) waste sites. The benchmarks presented in this report are values believed to be nonhazardous for the listed wildlife species.

2. AVAILABILITY AND LIMITATIONS OF TOXICITY DATA

Information on the toxicity of environmental contaminants to terrestrial wildlife can be obtained from several sources including the United States Environmental Protection Agency (EPA) Terrestrial Toxicity Data Base (TERRE-TOX, see Meyers and Schiller, 1985); U. S. Fish and Wildlife Service reports, EPA assessment and criteria documents, and Public Health Service toxicity profiles. Selected data from these sources are presented in tabular form in Appendix A. Pesticides were excluded from this compilation except for those considered to be likely contaminants on DOE reservations. Most of the available information on the effects of environmental contaminants on wildlife pertains to pesticides and little to industrial and laboratory chemicals of concern to DOE. Furthermore, the toxicity data that are available are often limited to severe effects of acute exposures [e.g., frank-effects levels (FELs), or concentration or dose levels causing 50% mortality to a test population (LC_{50} and LD_{50})]. Few studies have determined maximum safe exposure levels (no-observed-adverse-effect-levels, or NOAELs) for situations in which wildlife have been exposed over an entire lifetime or over several generations. [In this document, NOAEL refers to both dose (mg contaminant per kg animal body weight per day) and concentration (mg contaminant per kg or L of food or water).] Consequently, for nearly all wildlife species, a NOAEL for chronic exposures to a particular chemical must be estimated from less than ideal data (e.g., LD_{50} values) or from toxicity studies of the same chemical conducted on a different species of wildlife or on domestic or laboratory animals. In most cases, the only available information is from studies on laboratory animals (primarily rats and mice). Such laboratory studies represent a database whose use should be maximized; however, individual studies may be somewhat limited in scope and relevance to wildlife.

Wildlife NOAELs that are estimated from data on laboratory animals must be evaluated carefully, bearing in mind the possible limitations of the data. Studies on one particular group of animals, such as mice, may not be appropriate for evaluating potential toxicity to birds, amphibians, or even to other groups of mammals such as deer. Variations may also exist among species within the same family or genus. The reason is that significant physiological or biochemical differences may exist, such as in metabolism and disposition, which can alter the potential toxicity of the chemical in the tested species. Extrapolation of data from laboratory species to wildlife species may also be inappropriate if the inbred laboratory strains have an unusual sensitivity or resistance to the test compound. Differences in behavioral and ecological parameters (e.g., stress factors such as competition, seasonal changes in temperature or food availability, diseased states, or exposure to other contaminants) may make a wildlife species' sensitivity to an environmental contaminant different from that of a laboratory or domestic species.

Available studies on wildlife or laboratory species may not include evaluations of all significant endpoints for determining long-term effects on natural populations. Important data that may be lacking are potential effects on reproduction, development, and population dynamics following multigeneration exposures.

The available data may identify only the lowest-observed-adverse-effect-level (LOAEL), or an FEL, or LD_{50}. Estimating a NOAEL for a chronic exposure from such data can introduce uncertainty into the calculation.

If the NOAEL (or LOAEL) is based on a study in which the exposure period was subchronic (i.e., from several weeks to several months), then some uncertainty would be associated with estimating at what lower dose level the same effect might occur if the exposure occurred over an entire lifetime or for several generations.

The fewer the number of steps in the extrapolation process the lower the uncertainty in estimating the wildlife NOAEL. For example, extrapolating from a NOAEL for an appropriate toxic endpoint (i.e., reproductive or population effects) for white laboratory mice to white-footed mice that are relatively closely related and are of comparable body size would have a high level of reliability. Extrapolating from a LOAEL or FEL for a less ideal endpoint (i.e., change in enzyme activity) in laboratory mice to a non-rodent wildlife species would have a low level of reliability in predicting actual effects on natural populations. Extrapolation models for these wildlife extrapolations have not been developed as they have for aquatic biota (Suter, 1992).

3. METHODOLOGY

The general method to be used for these extrapolations is one based on an EPA methodology for deriving human toxicity values (e.g., Reference Values, Reportable Quantities, and unit risks for carcinogenicity) from animal data (EPA, 1986a, 1986b, 1988, 1989).

The first step in the procedure is to identify the toxicity data currently available for the chemicals of interest. NOAELs and LOAELs for the chemicals of concern at DOE facilities were obtained from the open literature, EPA review documents, and secondary sources Registry of Toxic Effects of Chemical Substances (RTECs) (Appendix B). NOAELs and LOAELs are daily dose levels normalized to the body weight of the test animals (e.g., milligrams of chemical per kilogram body weight per day). The presentation of toxicity data on a mg/kg/day basis allows comparisons across tests and across species with appropriate consideration for differences in body size. Studies have shown that numerous physiological functions such as metabolic rates, as well as responses to toxic chemicals, are a function of body size. Smaller animals have higher metabolic rates and are usually more resistant to toxic chemicals because of more rapid rates of detoxification (however, this may not be the case if the toxic effects of the compound are produced primarily by a metabolite). It has been shown that the best measure of differences in body size are those based on body surface area which, for lack of direct measurements, can be expressed in terms of body weight (bw) raised to the 2/3 power ($bw^{2/3}$) (EPA, 1980). If the dose (d) itself has been calculated in terms of unit body weight (i.e., mg/kg), then the dose per unit surface area (D) equates to

$$D = \frac{d \times bw}{bw^{2/3}} = d \times bw^{1/3} \tag{1}$$

The assumption is that the dose per body surface area (Equation 1) for species "a" and "b" would be equivalent:

$$d_a \times bw_a^{1/3} = d_b \times bw_b^{1/3} \tag{2}$$

Therefore, knowing the body weights of two species and the dose (d_b) producing a given effect in species "b," the dose (d_a) producing the same effect in species "a" can be determined:

$$d_a = d_b \times \frac{bw_b^{1/3}}{bw_a^{1/3}} = d_b \times (bw_b/bw_a)^{1/3} \tag{3}$$

This is the methodology that EPA uses in carcinogenicity assessments and reportable quantity documents for adjusting from animal data to an equivalent human dose (EPA, 1985, 1988). The same approach has been proposed for use in extrapolating from one animal species to another. However, it should be noted that this method has not been applied to wildlife by the EPA and that wildlife toxicologists commonly scale dose to body weight without incorporating the exponential factor of 2/3. The exponent has been retained for this report because no reason exists why different methods should be used to extrapolate from mice to humans and mice to foxes. The issue of appropriate scaling models for wildlife should be investigated.

For developing reference doses (RfDs), EPA uses a default factor of 0.1 to adjust an animal dose to an equivalent human dose. Using the body size scaling method outlined above results in an adjustment factor of about 0.07 when deriving an equivalent human dose from data for mice (using the standard body weight of 0.03 kg for mice and 70 kg for humans) and a factor of about 0.17 when deriving an equivalent human dose from data on rats (standard body weight 0.35 kg).

The ideal data set to use in the calculation would be the actual average body weights of the test animals used in the bioassay. When this information is not available, standard reference body weights for laboratory species can be used as indicated above (EPA, 1986). Body weight data for wildlife species are available from several secondary sources [i.e., the Mammalian Species series, published by the American Society of Mammalogists and Whitaker (1980) (see Appendix C)]. Often, only a range of adult body weight values is available for a species, in which case an average value must be estimated. A time-weighted average body weight for the entire life span of a species would be the most appropriate data set to use for chronic exposure situations; however, such data are usually not available. Because body weights of a species can vary geographically as well as by sex, population and/or sex-specific data may be appropriate for assessments of some chemicals. Unless otherwise stated, weight data represent means for both sexes and individuals from throughout the species geographic range.

If a NOAEL is available for the test species ($NOAEL_t$), then the equivalent NOAEL for a species of wildlife ($NOAEL_w$) can be calculated by using the adjustment factor for differences in body size:

$$NOAEL_w = NOAEL_t \times (bw_t/bw_w)^{1/3} \tag{4}$$

The dietary level or concentration in food (C_f, in mg/kg food) which would result in a dose equivalent to the NOAEL (assuming no other exposure through other environmental media) can be calculated from the food factor f, which is the amount of food consumed per unit body weight per day:

$$C_f = \frac{NOAEL_w}{f} \tag{5}$$

For laboratory mice, rats, and dogs, f values are 0.13, 0.05, and 0.025, respectively (EPA, 1980, 1985). Food factors for wildlife species are generally not available. In such cases, the food factor for the most closely related laboratory or domestic species can be used, or it can be derived from the rate of food consumption (F, in g/day or kg/day) and the body weight (bw, in g or kg):

$$f = \frac{F}{bw} \tag{6}$$

Rates of food consumption (F) for laboratory mammals can be estimated from allometric regression models derived from experimental data (EPA, 1987):

$$F = 0.054\ (bw)^{0.9451}\ \text{(moist diet)} \tag{7}$$

$$F = 0.049\ (bw)^{0.6087}\ \text{(dry diet)} \tag{8}$$

where F is the food consumed in kg/day, and bw is the body weight in kg.

Food consumption rates for wildlife can be estimated from allometric regression models based on metabolic rate (Nagy, 1987):

$$F = 0.235\ (bw)^{0.822}\ \text{(placental mammals)} \tag{9}$$

$$F = 0.621\ (bw)^{0.564}\ \text{(rodents)} \tag{10}$$

$$F = 0.577\ (bw)^{0.727}\ \text{(herbivores)} \tag{11}$$

$$F = 0.492\ (bw)^{0.673}\ \text{(marsupials)} \tag{12}$$

$$F = 0.648\ (bw)^{0.651}\ \text{(birds)} \tag{13}$$

$$F = 0.398\ (bw)^{0.850}\ \text{(passerine birds)} \tag{14}$$

where F is food consumed in g/day, and bw is the body weight in g.

The concentration of the contaminant in the drinking water of an animal (C_w, in mg/L) resulting in a dose equivalent to a $NOAEL_w$ can be calculated from the daily water consumption rate (W, in L/day) and the average body weight (bw_w) for the species:

$$C_w = \frac{NOAEL_w \times bw_w}{W} \tag{15}$$

The rate of water consumption per unit body weight (W/bw) is termed the water factor ω and can be used in a manner identical to that for the food factor.

If a wildlife species (such as mink or otter) feeds primarily on aquatic organisms, and the concentration of the contaminant in the food is proportional to the concentration in the water, then the food consumption rate (F, in kg/day) and the aquatic life bioaccumulation factor [BAF, the ratio (L/kg) of the concentration in tissue to its concentration in water, where both the organism and its prey are exposed] can be used to derive a final C_w value (EPA, 1993):

$$C_w = \frac{NOAEL_w \times bw_w}{W + (F \times BAF)} \tag{16}$$

Bioaccumulation factors may be predicted by multiplying the bioconcentration factor for the contaminant [BCF, ratio of concentration in food to concentration in water, (mg/kg)/(mg/L) = L/kg] by the appropriate food chain multiplying factor (FCM). For most inorganic compounds, BCFs and BAFs are assumed to equal; however, an FCM may be applicable for some metals if the organometallic form biomagnifies (EPA, 1993).

For laboratory mice, rats, and dogs, reference water consumption values are 0.0057, 0.049, and 0.61 L/day, respectively (EPA, 1986). Water consumption values for wildlife species are generally not available. In such cases, values for the most closely related laboratory or domestic species may be used in the calculation, or the rate of water consumption can be estimated from allometric regression models derived from experimental data for laboratory mammals (EPA, 1987):

$$W = 0.090\ (bw)^{1.2044}\ \text{(mammals, moist diet)} \tag{17}$$

$$W = 0.093\ (bw)^{0.7584}\ \text{(mammals, dry diet)} \tag{18}$$

where W is the water consumed in L/day, and bw is the body weight in kg.

The rate of water consumption can be estimated form allometric regression models derived from experimental data for mammalian wildlife :

$$W = 0.099\ (bw)^{0.90} \tag{19}$$

where W is the water consumed in L/day, and bw is the body weight in kg (Calder and Braun, 1983). A similar model has also been developed for birds (Calder and Braun, 1983):

$$W = 0.059\ (bw)^{0.67} \tag{20}$$

In cases where a NOAEL for a specific chemical is not available for either wildlife or laboratory species, but a LOAEL has been determined experimentally, the NOAEL can be estimated by applying an uncertainty factor (UF) to the LOAEL. In the EPA methodology, the LOAEL can be reduced by a factor of up to 10 to derive the NOAEL.

$$NOAEL = \frac{LOAEL}{\leq 10} \tag{21}$$

Although a factor of 10 is usually used in the calculation, the true NOAEL may be only slightly lower than the experimental LOAEL, particularly if the observed effect is of low severity. A thorough analysis of the available data for the dose-response function may reveal whether a LOAEL to NOAEL uncertainty factor of < 10 should be used.

If the only available data consist of a NOAEL (or a LOAEL) for a subchronic exposure of several weeks to several months or more, then the equivalent NOAEL or LOAEL for a chronic exposure can be estimated by applying another UF to the data. In the EPA methodology, a factor of up to 10 can be used:

$$\text{chronic } NOAEL = \frac{\text{subchronic } NOAEL}{\leq 10} \tag{22}$$

As in the case of the LOAEL to NOAEL adjustment, a factor of 10 is usually used in the calculation; however, other evidence, such as that for a related compound using the same toxicity endpoint, may suggest that an adjustment factor of < 10 is more appropriate. No data were found for any of the contaminants considered thereby suggesting the use of a LOAEL-NOAEL adjustment factor of < 10.

If the available data are limited to acute toxicity endpoints (FEL, frank-effects level) or to exposure levels associated with lethal effects (LD_{50}s), the estimation of NOAELs for chronic exposures are likely to have a wide margin of error because no standardized mathematical exists correlation between FEL or LD_{50} dose levels and NOAELs which can routinely be applied to all chemicals (exposure levels associated with NOAELs may range from 1/10 to 1/10,000 of the acutely toxic dose, depending on the chemical and species). However, if sufficient data exist for a related chemical a (i.e., if both an LD_{50} and a NOAEL have been determined), then this ratio should be used to estimate a $NOAEL_w$ from the $(LD_{50})_w$ for the compound of interest.

$$NOAEL_w = (LD_{50})_w \frac{NOAEL_a}{(LD_{50})_a} \tag{23}$$

4. APPLICATION OF THE METHODOLOGY

Two examples will be given illustrating the application of the extrapolation methodology for deriving NOAELs and environmental criteria for food and water. In one example (inorganic trivalent arsenic), the estimated values were derived primarily from data on laboratory species. In the second example [Aroclor 1254, a polychlorinated biphenyl (PCB) formulation], experimental data were available for two species of wildlife.

4.1 INORGANIC TRIVALENT ARSENIC

The toxicity of inorganic compounds containing arsenic depends on the valence or oxidation state of the arsenic as well as on the physical and chemical properties of the compound in which it occurs. Trivalent (As^{+3}) compounds such as arsenic trioxide (As_2O_3), arsenic trisulfide (As_2S_3), and sodium arsenite ($NaAsO_2$), are generally more toxic than pentavalent (As^{+5}) compounds such as arsenic pentoxide (As_2O_5), sodium arsenate (Na_2HAsO_4), and calcium arsenate [$Ca_3(AsO_4)_2$]. The relative toxicity of the trivalent and pentavalent forms may also be affected by factors such as water solubility; the more toxic compounds are generally more water soluble. In this analysis, the effects of the trivalent form of arsenic in water soluble inorganic compounds will be evaluated. In many cases, only total arsenic concentrations are reported so the assessor must conservatively assume that it is all trivalent.

4.1.1 Toxicity to Wildlife

The only wildlife toxicity information available for trivalent inorganic arsenic compounds pertains to acute exposures (Table 1; the data points listed are those reported in the literature).

Table 1. Toxicity of trivalent arsenic compounds to wildlife[a]

Species	Chemical	Conc. in Diet (mg/kg food)	Dose (mg/kg)	Effect	Reference
Whitetail deer *(Odocoileus virginianus)*	sodium arsenite	NR	34	Lethal dose	NAS, 1977
Mallard duck *(Anas platyrhynchos)*	sodium arsenite	NR	323 (single dose)	LD_{50}	NAS, 1977
	sodium arsenite	500	NR	32-day LD_{50}	NAS, 1977
California quail *(Callipepla californica)*	sodium arsenite	NR	47.6	LD_{50}	Hudson et al., 1984
Ring-necked pheasant *(Phasianus colchicus)*	sodium arsenite	NR	386 (single dose)	LD_{50}	Hudson et al., 1984

[a] Source of data and references: Eisler, 1988.
NR, Not reported.

For whitetail deer, the estimated lethal dose is 34 mg sodium arsenite/kg or 19.5 mg As/kg (NAS, 1977). For birds, estimated LD_{50} values for sodium arsenite range from 47.6 to 386 mg/kg body weight. Median lethality was also reported at a dietary level of 500 mg/kg food for mallard ducks. No information was found regarding chronic toxicity or reproductive or developmental effects. No chronic NOAELs or LOAELs are available; therefore, data on domestic or laboratory species must be used to identify NOAELs for wildlife.

4.1.2 Toxicity to Domestic Animals

Summary of toxicity of inorganic trivalent arsenic to domestic animals is summarized in Table 2 (data listed as given in the literature sources). For assessment purposes, the most useful study is the one identifying a NOAEL of 1.25 mg As/kg/day in dogs following a chronic (2 year) dietary exposure to sodium arsenite.

Table 2. Toxicity of trivalent arsenic compounds to domestic animals[a]

Species	Chemical	Conc. in Diet[b] or Water[c]	Dose[d]	Effect	Reference
MAMMALS:					
Cattle	arsenic trioxide	NR	33-55 mg/kg (single dose)	toxic	Robertson et al., 1984
	sodium arsenite	NR	1-4 g/animal	lethal	NRCC, 1978
Sheep	sodium arsenite	NR	5-12 mg/kg (single dose)	acutely toxic	NRCC, 1978
	"total arsenic"	58 mg As/kg food (3 wk)	NR	no adverse effects	Woolson, 1975
Horse	sodium arsenite	NR	2-6 mg/kg/day (14 wk)	lethal	NRCC, 1978
Pig	sodium arsenite	500 mg As/L	100-200 mg/kg	lethal	NAS, 1977
Cat	arsenite	NR	1.5 mg/kg/day	chronic toxic effects	Pershagen and Vahter, 1979
Dog	sodium arsenite	NR	50-150 mg/animal	lethal	NRC, 1978
	sodium arsenite	125 mg As/kg food (2 year)	3.1 mg As/kg/day	reduced survival	Byron et al., 1967
	sodium arsenite	50 mg As/kg food (2 year)	1.25 mg As/kg/day	NOAEL	Byron et al., 1967
	sodium arsenite	NR	4 mg/kg/day (58 days) + 8 mg/kg (125 days)	LOAEL; liver enzyme changes	Neiger and Osweiler, 1989
Mammals	arsenic trioxide	NR	3-250 mg/kg	lethal	NAS, 1977
Mammals	sodium arsenite	NR	1-25 mg/kg	lethal	NAS, 1977

Table 2. Toxicity of trivalent arsenic compounds to domestic animals[a]					
Species	Chemical	Conc. in Diet[b] or Water[c]	Dose[d]	Effect	Reference
BIRDS:					
Chicken *(Gallus gallus)*	arsenite	NR	0.01-1.0 μg As/embryo	≤34% dead	NRCC, 1978
	arsenite	NR	0.03-0.3 μg As/embryo	threshold for malformations	NRCC, 1978

[a] Sources of data and references: USAF, 1990; Eisler, 1988. NR Not reported.
[b] Dietary level given as mg/kg food.
[c] Concentration in water given as mg/L.
[d] Dose refers to compound unless otherwise stated.

4.1.3 Toxicity to Laboratory Animals (Rodents)

Selected acute and chronic toxicity data for trivalent arsenic in rats and mice are summarized in Table 3 (dietary or drinking water concentrations were converted to daily dose levels as discussed earlier or from more specific information given in the original source). For environmental assessment purposes, the most useful toxicity values reported are the NOAELs of 0.7 and 2.44 mg As/kg/day reported for rats and the LOAEL of 0.38 mg As/kg/day for reproductive effects (decreased litter size) in mice exposed for three generations. The reported value of 4.88 mg As/kg can also be considered a NOAEL for population effects in rats, since the only observed adverse effect was a slight reduction in growth of females.

Table 3. Toxicity of trivalent arsenic compounds to laboratory animals					
Species	Chemical	Conc. in Diet[a] or Water[b]	Dose (mg As/kg)	Effect	Reference
Rat	arsenic trioxide	NR	15.1 (1 dose)	LD_{50}	Harrison et al., 1958
	sodium arsenite	125 mg As/kg food (2 year)	9.75	FEL, bile duct enlargement	Byron et al., 1967
	sodium arsenite	62.5 mg As/kg food (2 year)	4.88	reduced growth in females; no effect on survival	Byron et al., 1967
	sodium arsenite	31.25 mg As/kg food (2 year)	2.44	NOAEL	Byron et al., 1967
	sodium arsenite	5 mg As/L (lifetime)	0.7	NOAEL	Schroeder et al., 1968
Mouse	arsenic trioxide	NR	9.4 (1 dose)	LD_{50}	Harrison et al., 1958
	sodium arsenite	NR	a. 23 (1 dose) b. 11.5 (1 dose)	a. Fetal mortality b. NOAEL	Baxley et al., 1981

Table 3. Toxicity of trivalent arsenic compounds to laboratory animals					
Species	Chemical	Conc. in Diet[a] or Water[b]	Dose (mg As/kg)	Effect	Reference
	arsenic trioxide	75.8 mg As/L (lifetime)	21.6	LOAEL; mild hyperkeratosis/epidermal hyperplasia	Baroni et al., 1963
	soluble arsenite	5 mg As/L + 0.06 mg As/kg food (3 generations)	0.38[c] 0.95[d]	LOAEL; incr. in male to female ratio; decr. in litter size	Schroeder and Mitchener, 1971
	sodium arsenite	5 mg As/L + 0.46 mg As/kg food (lifetime)	0.38[c]	LOAEL; slight decr. in median life span; no effect on growth	Schroeder and Balassa, 1967
	sodium arsenite	0.5 mg As/L (3 weeks)	0.10	LOAEL; immunosuppressive effects	Blakely et al., 1980

[a] Dietary level in mg/kg food.
[b] Concentration in water given as mg/L.
[c] As estimated by Schroeder and Balassa, 1967.
[d] As estimated from the concentration in water, a water consumption of 0.0057 L/day, and a standard reference body weight of 0.03 (Equations 15).

4.1.4 Extrapolations to Wildlife Species

Extrapolated toxicity values for trivalent arsenic for representative wildlife species are shown in Table 4 based on selected data from Tables 2 and 3. The values for the concentration in food (C_f) represent maximum acceptable concentrations assuming no additional exposure through water consumption. Similarly, the concentration in water (C_w) is the maximum acceptable concentration assuming no additional exposure through dietary intake. If dietary and water intake contributed equally to the exposure, and absorption rates through the GI tract were similar, then the equivalent dietary level and water concentration would be one-half of the listed values. Exposures through inhalation or direct dermal contact are not taken into consideration in these calculations. If these other exposure routes are significant, then the maximum acceptable C_f and C_w must be adjusted accordingly.

The NOAEL value listed for the white-footed mouse is derived from the experimental LOAEL for laboratory mice. Two values are given for the LOAEL: 0.95 mg/kg is based on the standard EPA water consumption rate for mice (0.0057 L/day), and 0.38 mg/kg is the dose estimate based on a water intake of 6 mL/100 g bw which was calculated by Schroeder and Balassa (1967) in a related study using the same exposure protocol. A range of values is given for the NOAEL for laboratory mice because there is the uncertainty as to whether the true NOAEL is only slightly below the experimental LOAEL or as much as 1/10 of the lowest reported LOAEL (the EPA default value as given in Equation 21). The NOAEL for the white-footed mouse is derived from Equation 4 which adjusts the values for differences in body size. Because the body weights of the two species are similar, the range in the NOAELs is almost identical.

Also using Equation 4, the NOAEL for the cotton rat is derived from the NOAEL for the laboratory rat, and that for the red fox from the NOAEL for the dog. All four values are greater than the NOAEL for the laboratory mouse whereas the body size differences alone would suggest that the mice should have the higher NOAEL. There can be several explanations for these differences. Mice may be unusually sensitive to trivalent arsenic; however, the LD_{50} data for rats and mice do not support this conclusion. The mouse data were derived from a three-generation bioassay in which reproductive effects (reduced litter size) were identified. Conversely, the rat study consisted of a lifetime exposure, while the dog study was for only 2 years; reproductive effects were not evaluated for rats or dogs. Therefore, it is possible that reproductive effects similar to those seen in mice might occur in rats and dogs at or below the listed NOAELs if multigeneration studies were conducted.

The calculations given in Table 4 for the NOAEL for whitetail deer illustrate the problems that can arise if data for different species are used in the extrapolation procedure. The estimated NOAELS (from Equation 4) for whitetail deer are $\geq 0.003 < 0.008$ mg/kg as derived from the range of estimated mouse NOAELS, 0.81 mg/kg as derived from the rat data, and 0.74 mg/kg as derived from the dog data. These values convert to dietary levels of $\geq 0.10 < 0.26$ mg/kg food, 27.9 mg/kg food and 25.5 mg/kg food, respectively. A dietary NOAEL of 5.8 mg/kg food (total arsenic) for sheep (derived from a NOAEL of 58 mg/kg food for a 3-week exposure by using Equation 23) suggests that the NOAEL for whitetail deer for nonreproductive effects is likely to be close to the values extrapolated from the rat or dog studies. However, the most conservative estimate, based on potential reproductive effects, would be the lowest value extrapolated from the mouse data (0.003 mg/kg/day).

4.2 POLYCHLORINATED BIPHENYLS

Polychlorinated biphenyls occur in a variety of different formulations consisting of mixtures or individual compounds. The most well-known of these formulations is the Aroclor series (i.e., Aroclor 1016, Aroclor 1242, Aroclor 1248, Aroclor 1254, etc.). The Aroclor formulations vary in the percent chlorine, and, generally, the higher the chlorine content the greater the toxicity. This analysis will focus on Aroclor 1254 for which chronic toxicity data are available for two species of wildlife.

4.2.1 Toxicity to Wildlife

Wildlife toxicity test data for Aroclor 1254 is limited to two species—white-footed mice and mink (Table 5). In both species the reproductive system and developing embryos are adversely affected by both acute and chronic exposures. A dietary LOAEL of 10 mg/kg food (1.7 mg/kg/day) was reported for white-footed mice, and a dietary NOAEL of 1 mg/kg food (0.07 mg/kg) was reported for mink.

4.2.2 Toxicity to Domestic Animals

No information is available on the toxicity of Aroclor 1254 to domestic animals.

4.2.3 Toxicity to Laboratory Animals

As shown in Table 6, laboratory studies have identified a dietary NOAEL of < 5 mg/kg food (< 0.25 mg/kg/day) for rats exposed to Aroclor 1254 over two generations. Reported LOAELs are 4-10 times higher than the NOAEL, and the single-dose LD_{50} is about 4000-fold higher than the NOAEL. As shown by the dose levels that produce fetotoxicity during gestation, rabbits appear to be less sensitive than rats.

Table 4. Selected wildlife toxicity values for trivalent inorganic arsenic[a,b]									
Species	BW (kg)	Food factor	Water Intake (L/day)	LOAEL (mg As/kg)	NOAEL (as As) (mg/kg)	NOAEL (as As) mg/kg Diet[(6)]	NOAEL (as As) mg/L Water[(5,8)]	LD_{50} (mg As/kg)	$\frac{NOAEL}{LD_{50}}$
Mouse (lab)	0.030	0.13	0.0057 6 mL/100 g	0.95[c] 0.38[d]	≥0.095[(1)] ≥0.038[(1)]			39.4	<0.02 >0.001
White-footed mouse	0.02	0.17[(10,8)]	0.003[(9)]		<0.109[e (4)] ≥0.043[(4)]	<0.64 ≥0.25	<0.73 ≥0.29		
Rat (lab)	0.35	0.05	0.049		4.48	89.6	32.0	15.1	0.30
Cotton rat	0.15	0.070[(10,8)]	0.018[(9)]		5.94[f (4)]	84.9	49.5		
Dog	12.7	0.025	0.61		1.25	50.0	26.0		
Red fox	6.0	0.050[(9,8)]	0.50[(9)]		1.60[g (4)]	32.0	19.2		
Sheep						5.8[(2)]			
Whitetail deer								>19.5	
	60	0.029[(11,8)]	3.9[(9)]		<0.008[e] ≥0.003[e (4)]	<0.26 ≥0.10	<0.11 ≥0.05		
	60	0.029[(11,8)]	3.9[(9)]		0.81[f (4)]	27.9	12.5		
	60	0.029[(11,8)]	3.9[(9)]		0.74[g (4)]	25.5	11.42		

[a] Numbers in parentheses refer to equations in text used to derive the values.
[b] Shaded values are experimentally derived.
[c] Based on EPA water consumption rate for mice.
[d] Based on data given in Schroeder and Balassa, 1967.
[e] Extrapolated from data for laboratory mice.
[f] Extrapolated from data for laboratory rat.
[g] Extrapolated from data for dog.

Table 5. Toxicity of Aroclor 1254 to wildlife					
Species	Concentration in Diet	Daily Dose (mg/kg)	Expos. Period	Effect	Reference
MAMMALS:					
White-footed mouse	400 mg/kg food[a]	68	2-3 wk	FEL, reprod.	Sanders and Kirkpatrick, 1975
	200 mg/kg food[a]	34	60 d	LOAEL, reproduction	Merson and Kirkpatrick, 1976
	10 mg/kg food[a]	1.7	18 mo	LOAEL, reproduction	Linzey, 1987
Mink	6.5 mg/kg food	1.25	9 mo	LC_{50}	Ringer et al., 1981; ATSDR, 1989a
	2 mg/kg food	0.38[b] 0.14[c]	9 mo	FEL/LOAEL, fetotoxicity	Aulerich and Ringer, 1977
	1 mg/kg food	0.07[c]	5 mo	NOAEL	Aulerich and Ringer, 1977

[a] Estimated from Equation 5 using a food factor of 0.17 derived from Equation 10 and a body weight of 0.02 kg.
[b] Reported by ATSDR (1989); based on food intake of 150 g/day and mean body weight of 0.8 kg.
[c] Estimated from Equations 5, 6, and 9, and a body weight of 0.8 kg (as reported by Bleavins et al., 1980).

Table 6. Toxicity of Aroclor 1254 to laboratory animals					
Species	Concentration in Diet	Daily Dose (mg/kg)	Exposure Period	Effect	Reference
MAMMALS:					
Rat		1010	1 day	LD_{50}	Garthoff et al., 1981
	50 mg/kg food	2.5	During gestation	LOAEL, for fetotoxicity	Collins and Capen, 1980
	25 mg/kg food	1.25	104 week	LOAEL, reduced survival	NCI, 1978; ATSDR, 1989a
	>20 mg/kg food	>1.0	2 generations	FEL/LOAEL, reduced litter size	Linder et al., 1974
	<5 mg/kg food	<0.25	2 generations	NOAEL	Linder et al., 1974
Rabbit		10.0	During gestation (28 days)	NOAEL for fetoxicity	Villeneuve et al., 1971
		12.5	During gestation (28 days)	FEL, fetal deaths	Villeneuve et al., 1971

4.2.4 Extrapolations to Wildlife Species

Experimentally derived and extrapolated toxicity values for Aroclor 1254 for representative wildlife species are shown in Table 7. Of the experimentally derived data, the lowest NOAEL is that obtained from the mink (0.07 mg/kg). Because reproductive changes can adversely affect natural population dynamics, the 9-month exposure can be considered to be equivalent to a chronic condition, and no subchronic to chronic adjustment is needed in the data (as from Equation 22). A body weight of 0.8 kg is used in the calculation because this is the time-weighted average body weight for females from birth to 10 months of age, the time at which they reach reproductive maturity (EPA, 1987).

The NOAELs shown in Table 7 illustrate how extrapolated values can vary depending on which set of experimental data is used. The NOAELs for mink that were derived from the data for the white-footed mouse and laboratory rat are 0.05 mg/kg and 0.19 mg/kg, respectively, whereas the NOAEL from the experimental mink data is 0.07 mg/kg indicating that the mouse data provide a better estimate of the toxicity of Aroclor 1254 to mink.

The extrapolated NOAELs for the cotton rat and whitetail deer show that there is a three- to four-fold difference between the values derived from the mouse data and those derived from the laboratory rat, whereas the values derived from the mink and mouse data are quite similar. The most conservative benchmark value for Aroclor 1254 would be the NOAEL for whitetail deer (0.012 mg/kg) extrapolated from the data for the white-footed mouse; however, the NOAEL derived from the mink data (0.017 mg/kg) is more reliable since the mink value was based on an experimentally derived NOAEL whereas the white-footed mouse value was based on an experimentally derived LOAEL.

For piscivorous species such as mink, a final water quality criterion for Aroclor 1254 can be derived from Equation 16. Bioconcentration factors (BCF) for Aroclor 1254 range from 34,000 to 47,000 for trout and from 34,000 to 307,000 for fathead minnow (Verschueren, 1983). The octanol-water partition coefficient (log P_{oct}) ranges from 5.6-8.0 (USAF,1989). To be conservative, the diet of mink is assumed to consist entirely of small fish (trophic level 3, Table 8); therefore, the FCM for Arochlor 1254 ranges from 1 to 7.5. [A minimum FCM of 1 is assumed where log P_{oct} = 8.0. FCMs for values of log P_{oct} > 6.5 are undefined; the U.S. EPA (1993) suggests the FCM = 1.0 be used in the absence of appropriate data.]

For a NOAEL of 0.07 mg/kg and a minimum BAF of 34,000 (BCF=34,000; FCM=1), the final water quality criterion for mink would be 0.028 μg/L for animals having an average body weight of 0.8 kg (F=0.057 kg/day; W=0.08 L/day) and 0.032 μg/L for the animals of average body weight of 1.5 kg (F=0.096 kg/day; W=0.14 L/day). For a maximum BAF of 2,302,500 (BCF=307,000; FCM=7.5), the final criterion would be 427 pg/L for 0.8 kg animals and 475 pg/L for the larger mink.

5. SITE-SPECIFIC APPLICATION OF THE METHODOLOGY

The examples given earlier in this report for trivalent inorganic arsenic and Aroclor 1254 illustrate the extent of the analysis that is required for an understanding of the toxicity of environmental contaminants to wildlife and for the development of benchmark values for mammals. For a complete risk assessment at a particular site similar analyses would be needed for all the chemicals present, as well as information on their physical and chemical state, their concentration in various environmental media, and their bioavailability. The last factor is especially important in estimating environmental impacts. For example, insoluble substances tightly bound to soil particles are unlikely to be taken up by organisms even if ingested. In addition, the chemical or valence state of a contaminant may alter its toxicity such that the different chemical or valence states may have to be treated separately as in the case of trivalent arsenic. Similar problems can be encountered with formulations consisting of mixtures of compounds such as the Aroclors, and each may have to be evaluated separately, unless the relative potency of each of the components can be determined.

For a site-specific assessment, information on the types of wildlife species present, their average body size, and food and water consumption rates would also be needed for calculating

Table 7. Selected wildlife toxicity values for Aroclor 1254[a,b]									
Species	bw (kg)	Food factor	Water (L/day)	LOAEL (mg/kg/d)	NOAEL (mg/kg/d)	Benchmarks: Diet[(5)] (mg/kg food)	Benchmarks: Water[(13)] (mg/L)	LD_{50} (mg/kg)	NOAEL/ LD_{50}
EXPERIMENTALLY DERIVED VALUES:									
White-footed mouse	0.02	0.17[(10),(8)]	0.003[(10)]	1.7	0.17[(11)]	1.0[(5)]	1.1		
Rat (lab)	0.35	0.05	0.049		0.25	5.0	1.8	1,010	0.0002
Mink	0.80	0.07[(9),(8)]	0.081[(10)]		0.07[(5)]	1	0.69[f]	1.25	0.06
EXTRAPOLATED VALUES:									
Mink[c]	0.80	0.07[(9),(8)]	0.081[(10)]		0.05[(4)]	0.71[(5)]	0.49[(13)]		
Mink[d]	0.80	0.07[(9),(8)]	0.081[(10)]		0.19[(4)]	2.71[(5)]	1.88[(13)]		
Cotton rat[c]	0.15	0.07[(10),(8)]	0.018[(10)]		0.09[(4)]	1.24[(5)]	0.75[(13)]		
Cotton rat[d]	0.15	0.07[(10),(8)]	0.018[(10)]		0.33[(4)]	4.70[(5)]	2.75[(13)]		
Cotton rat[e]	0.15	0.07[(10),(8)]	0.018[(10)]		0.12[(4)]	1.75[(5)]	1.00[(13)]		
Whitetail deer[c]	60	0.029[(11),(8)]	3.9[(10)]		≥0.012[(4)]	0.41[(5)]	0.18[(13)]		
Whitetail deer[d]	60	0.029[(11),(8)]	3.9[(10)]		0.045[(4)]	1.55[(5)]	0.69[(13)]		
Whitetail deer[e]	60	0.029[(11),(8)]	3.9[(10)]		0.017[(4)]	0.59[(5)]	0.26[(13)]		

[a] Numbers in parentheses refer to equations in text.
[b] Shaded values are experimentally derived.
[c] Based on the white-footed mouse NOAEL of 0.17 mg/kg.
[d] Based on the laboratory rat NOAEL of 0.25 mg/kg.
[e] Based on the mink NOAEL of 0.07 mg/kg.
[f] See text for calculation of Final Criterion value.

Table 8. Aquatic food chain multiplying factors[a]			
Log P_{ow}	Prey Trophic Level[b]		
	2	3	4
≤3.9	1.0	1.0	1.
4.0	1.1	1.0	1.
4.1	1.1	1.1	1.
4.2	1.1	1.1	1.
4.3	1.1	1.1	1.
4.4	1.2	1.1	1.
4.5	1.2	1.2	1.
4.6	1.2	1.3	1.
4.7	1.3	1.4	1.
4.8	1.4	1.5	1.
4.9	1.5	1.8	2.
5.0	1.6	2.1	2.
5.1	1.7	2.5	3.
5.2	1.9	3.0	4.
5.3	2.2	3.7	5.
5.4	2.4	4.6	8.
5.5	2.8	5.9	11.
5.6	3.3	7.5	16.
5.7	3.9	9.8	23.
5.8	4.6	13.0	33.
5.9	5.6	17.0	47.
6.0	6.8	21.0	67.
6.1	8.2	25.0	75.
6.2	10.0	29.0	84.
6.3	13.0	34.0	92.
6.4	15.0	39.0	98.
6.5	19.0	45.0	100.
>6.5	([c])	([c])	([c])

[a] From U.S. EPA 1993.
[b] Trophic level: 2 = zooplankton; 3 = small fish; 4 = piscivorous fish, including top predators.
[c] For chemicals with log P_{ow} > 6.5, FCM can range from 0.1-100. Such chemicals should be evaluated individually. Without chemical-specific data, an FCM of 1.0 should be used (EPA, 1993

NOAELs and environmental criteria. Use of observed values for food and water consumption (if available) are recommended over rates estimated by allometric equations. A list of avian and mammalian species for the DOE Oak Ridge site is given in Appendix C. Since body size of some species can vary geographically, the more specific the data are to the local population the more reliable will be the estimates. Data on body size is especially important in the extrapolation procedure, particularly if calculations of the NOAEL and environmental concentrations are based solely on the adjustment factor as shown in Equation 4. In such cases the lowest NOAEL will be derived from the species with the largest body size.

Information on physiological, behavioral, or ecological characteristics of these species can also be of special importance in determining if certain species are particularly sensitive to a particular chemical or groups of chemicals. If one species occurring at a site is known to be unusually sensitive to a particular contaminant, then the criteria should be based on data for that species (with exceptions noted in the following paragraphs). Similarly, extrapolations from studies on laboratory animals should be based on the most sensitive species unless there is evidence that this species is unusually sensitive to the chemical (e.g., laboratory mice exposed to trivalent inorganic arsenic [Table 4]).

Physiological and biochemical data may be important in determining the mechanism whereby a species' sensitivity to a chemical may be enhanced or diminished. Such information would aid in determining whether data for that species would be appropriate for developing criteria for other species. For example, if the toxic effects of a chemical are related to the induction of a specific enzyme system, as is the case with PCBs, then it would be valuable to know whether physiological factors (enzyme activity levels per unit mass of tissue or rates of synthesis of the hormones affected by the induced enzymes) in the most sensitive species are significantly different from those of other species of wildlife. Furthermore, if the most sensitive species, or closely related species, do not occur at a particular site, then a less stringent criteria might be acceptable.

Physiological data may also reveal how rates of absorption and bioavailability vary with exposure routes and/or exposure conditions. Gastrointestinal absorption may be substantially different depending on whether the chemical is ingested in the diet or in drinking water. Thus, a NOAEL based on a laboratory drinking water study may be inappropriate to use in extrapolating to natural populations that would only be exposed to the same chemical in their diet. The diet itself may affect gastrointestinal absorption rates. In the case of the mink exposed to PCBs, their diet consists primarily of contaminated fish in which the PCBs are likely to be concentrated in fatty tissues. This may result in a different rate of gastrointestinal absorption than that occurring in laboratory rodents dosed with PCBs in dry chow.

Behavioral and ecological data might also explain differences in sensitivity between species. Certain species of wildlife may be more sensitive because of higher levels of environmental stress to which they are subjected. This may be especially true of populations occurring at the periphery edges of their normal geographic range. Conversely, laboratory animals maintained under stable environmental conditions of low stress may have higher levels of resistance to toxic chemicals.

As a first step in developing wildlife criteria for chemicals of concern at DOE sites, relevant toxicity data for wildlife and laboratory animals have been compiled (Appendixes A and B). These data consist primarily of NOAELs, LOAELs, and LD_{50}s for mammalian species. No methodology is currently available for extrapolating from mammalian studies to nonmammalian terrestrial vertebrates (i.e., birds, reptiles, and amphibians), and no attempt has been made to do so in this report. The limited experimental data on birds pertain largely to acute toxicity; however, a few subchronic and chronic studies have been reported and these are cited where appropriate. No pertinent data on non-pesticide chemicals were found for amphibians, reptiles, or terrestrial invertebrates. Additional chronic exposure studies are needed before toxicological benchmarks can be developed for these groups.

The ideal data to use for evaluating chronic exposures is the time-weighted average (TWA) body weight for the entire life span of the species. While rarely available for wildlife, the TWA body weight for mink through age 450 days was calculated to be about 1.35 kg (EPA, 1987). The TWA body weight for the entire life span was estimated to be about 1.5 kg, only slightly less than average adult size of about 1.6 kg. Very approximate estimates of average body weights for the other species were based on the available data (Table 9). These values were then used to calculate body surface area scaling factors from Equation 4 (Table 9) and also to derive food factors from Equations 6 and 9-11 and water consumption values from Equation 19 (Table 10).

For piscivorous species (mink, belted kingfisher, great blue heron) that may be exposed to contaminants through both diet and water, a final water criterion was calculated by using the aquatic life BAF as given in Equation 16. BAFs were estimated by multiplying the aquatic life bioconcentration factor (BCF) for the contaminant by the food chain multiplier (Table 8) appropriate for the wildlife species of concern (EPA, 1993). In cases where the BCF for a particular compound was not available, it was estimated from the octanol-water partition coefficient of the compound by the following relationship (Lyman et al., 1980):

$$\log BCF = 0.76 \log P_{oct} - 0.23 \quad (24)$$

The BCF can also be estimated from the water solubility of a compound by the following regression equation (Lyman et al., 1982):

$$\log BCF = 2.791 - 0.564 \log WS \quad (25)$$

where WS is the water solubility in mg/kg water.

Pertinent log P values, water solubility data, and reported or calculated BCF values for the chemicals on the preliminary DOE list are included on Table 11. The BCF values listed represent the ranges determined by the various methods as well as any experimental values reported in the literature. Ideally, the BCF values used should be those for the primary prey species; however, because this information is rarely available, the ranges provide upper and lower bounds to the estimate.

The results of the analyses are presented in Tables 12 (mammals) and 13 (birds). Because of the consistency of the body weight differences for the selected mammalian wildlife species, the calculated NOAELs exhibit about a 15-fold range between the species of smallest body size (short-tailed shrew) and that of the largest body size (whitetail deer). In terms of dietary intake, the range in values is much less (2–3 fold) thereby indicating that equivalent dietary levels of a chemical result in nearly equivalent doses between species because food intake is a function of metabolic rate which, in turn, is a function of body size (EPA, 1980). However, according to EPA, the correlation is not exact because food intake also varies with moisture and caloric content of the food, and it should be noted that in laboratory feeding experiments, the test animals are usually dosed with the chemical in a dry chow. Therefore, it would be expected that the food factor for a species of wildlife would be relatively higher than that of a related laboratory species of comparable body size.

Few long-term, multigeneration studies on wildlife or laboratory animals have been conducted on chemicals of concern to the DOE. Consequently, the extrapolated NOAELs listed in Tables 12 and 13 cannot be considered as absolute safe levels, particularly in terms of potential population effects since subtle reproductive changes may occur at or below levels producing overt toxicological signs. Although more in-depth analyses of the toxicity of each chemical, as given in preceding paragraphs for trivalent arsenic and Aroclor 1254, might provide some indication as to whether such effects might occur, only multigeneration studies would provide conclusive results.

Table 9. Body size scaling factors

Experimental Animals		Wildlife		
Species	Body Weight[a] (bw_t in kg)	Species	Body weight[b] (bw_w in kg)	Scaling factor $(bw_t/bw_w)^{1/4}$
rat	0.35	short-tailed shrew	0.015	2.828
rat	0.35	white-footed mouse	0.02	2.596
rat	0.35	cottontail rabbit	1.0	0.705
rat	0.35	mink	1.5	0.616
rat	0.35	red fox	6.0	0.388
rat	0.35	whitetail deer	60.0	0.180
mouse	0.03	short-tailed shrew	0.015	1.26
mouse	0.03	white-footed mouse	0.02	1.14
mouse	0.03	cottontail rabbit	1.0	0.311
mouse	0.03	mink	1.5	0.271
mouse	0.03	red fox	6.0	0.171
mouse	0.03	whitetail deer	60	0.079
dog	12.7	short-tailed shrew	0.015	9.439
dog	12.7	white-footed mouse	0.02	8.595
dog	12.7	cottontail rabbit	1.0	2.333
dog	12.7	mink	1.5	2.038
dog	12.7	red fox	6.0	1.284
dog	12.7	whitetail deer	60.0	0.596
rabbit	3.8	short-tailed shrew	0.015	6.32
rabbit	3.8	white-footed mouse	0.02	5.75
rabbit	3.8	cottontail rabbit	1.0	1.56
rabbit	3.8	mink	1.5	1.36
rabbit	3.8	red fox	6.0	0.859
rabbit	3.8	whitetail deer	60.0	0.399
human	70	short-tailed shrew	0.015	16.664
human	70	white-footed mouse	0.02	15.183
human	70	cottontail rabbit	1.0	4.121
human	70	mink	1.5	3.600
human	70	red fox	6.0	2.268
human	70	whitetail deer	60	1.053

[a] Standard reference values used by EPA.
[b] Estimated from data in Appendix C-1.

Table 10. Extrapolation factors[a]					
Species	bw (kg)	Food Intake (kg/day)	Food factor (*f*)	Water Intake (L/day)[(15)]	Water factor (ω)
rat	0.35[b]	0.027	0.050[b]	0.049[b]	0.14
mouse	0.03[b]	0.004	0.13[b]	0.0057[b]	0.19
rabbit	3.8[b]	0.186	0.049[b]	0.41[b]	0.108
dog	12.7[b]	0.317	0.025[b]	0.61[b]	0.048
short-tailed shrew	0.015[c]	0.002	0.19	0.002	0.15
white-footed mouse	0.02[c]	0.003	0.17[(10),(9)]	0.003[(16)]	0.15
cottontail rabbit	1.0[c]	0.069	0.069[(11),(9)]	0.099[(16)]	0.099
mink	1.5[c]	0.096	0.064[(8),(9)]	0.143[(16)]	0.095
red fox	6.0[c]	0.300	0.050[(8),(9)]	0.497[(16)]	0.083
whitetail deer	60[c]	1.717	0.0286[(11),(9)]	3.94[(16)]	0.066

[a] Numbers in parentheses refer to equations in text.
[b] EPA standard reference values.
[c] Average adult body weights estimated from data given in Appendix C-1.
[d] The water factor is the water intake divided by the body weight.

Table 11. Octanol-water partition coefficients, water solubility data and bioconcentration factors				
Chemical	log P	Water Solubility (mg/L)	BCF	References
Acetone	-0.24	infinite	0.39-0.99	USAF, 1989
Benzene	1.56-2.28	1,780	6.5-23	USAF, 1989; Verschueren, 1983
Benzo[a]pyrene	6.06	3.8×10^{-3}	23,746[c]	Mabey et al. 1982
Carbon tetrachloride	0.35-2.83	800	2-83	USAF, 1989
Chlordane	5.48	0.056	14100	USAF, 1989
Chloroform	1.97	822	15-19	USAF, 1989
Cyanide	0.66	miscible	2-72	USAF, 1989
DDT	6.36	0.0031-0.0034	38,000-110,000	USAF, 1989
Di-N-butylphthalate	4.57	4500	8.9-1800	USAF, 1989
1,1-Dichloroethylene	2.13	400	6-24	USAF, 1989
1,2-Dichloroethylene	1.86	3,500	4.5-15	USAF, 1989

Table 11. Octanol-water partition coefficients, water solubility data and bioconcentration factors

Chemical	log P	Water Solubility (mg/L)	BCF	References
Di-2-ethylhexylphthalate	3.98; 5.11	4	330-6200	USAF, 1989
Ethyl acetate		79,000-86,000	1.0-1.1	Verschueren, 1983
Fuel Oil No. 2	3.30-7.06	5	249	USAF, 1989
Fuel Oil No. 6	3.30-7.06	5	249	USAF, 1989
Methanol	-0.82; -0.66		0.14-0.58	Verschueren, 1983
Methylene chloride	1.25	13,200	5-80	USAF, 1989
Methyl ethyl ketone	0.29	353,000	0.1-2	USAF, 1989
4-Methyl-2-pentanone (Methyl isobutyl ketone)		17,000-19,100	2.4-2.5	Verschueren, 1983; Merck Index
PCBs:				
Aroclor 1016	5.30-5.60	0.2-0.9	992-10,617	USAF, 1989
Aroclor 1242	5.30-6.10	0.2-0.7	992-25,468	USAF, 1989
Aroclor 1254	5.60-8.00	0.1-0.07	1,442-707,945	USAF, 1989
Aroclor 1260	6.10-9.30	0.0027	2,693-6,886,523	USAF, 1989
2,3,7,8 TCDD	6.15-7.28	7.91; 19.3 mg/L	27,797-200,816[a]	ATSDR, 1989b
Tetrachloroethylene	1.59; 3.14	150	9.5-143	Verschueren, 1983; USAF, 1989
Tetrahydrofuran		miscible		Verschueren, 1983
Toluene	2.73; 2.80	515	26-79	USAF, 1989; Verschueren, 1989
1,1,1-Trichloroethane	2.49	950	5.6-46	USAF, 1989
Trichloroethylene	2.42	1,000	13-41	USAF, 1989
Vinyl chloride	1.23	1,100	0.8-6	USAF, 1989
Xylene	3.16		7	USAF, 1989

[a] Values estimated using equation 24.

Table 12. Toxicological benchmarks for selected mammalian wildlife species[a]									
		Experimental Values[b]			Extrapolated Values for Chronic Exposures				
						Toxicological Benchmarks			
Chemical - exp. animal	Wildlife	LOAEL (mg/kg/day)	NOAEL (mg/kg/day)	Endpoint	NOAEL (mg/kg/day)	Diet[d] (mg/kg food)	Water[c,e] (mg/L)	Final Water Crit. (mg/L)[f]	References (LOAEL/NOAEL)
Acetone - rat		500 (90 days)	100 (90 days)	liver and kidney	10[c]				EPA, 1986c
	short-tailed shrew				28	148	188		
	white-footed mouse				26	153	176		
	cottontail rabbit				7.1	81	71		
	mink				6.2	97	65	39-51	
	red fox				3.9	78	47		
	whitetail deer				1.8	64	28		
Soluble arsenite - mouse		0.95 (3 gen)		reproduction	0.095[c]				
	short-tailed shrew				0.12	0.63	0.79		Schroeder and Mitchner, 1971
	white-footed mouse				0.11	0.65	0.74		
	cottontail rabbit				0.03	0.34	0.30		
	mink				0.026	0.41	0.27		
	red fox				0.017	0.33	0.20		
	whitetail deer				0.008	0.27	0.12		

Table 12. Toxicological benchmarks for selected mammalian wildlife species[a]									
		Experimental Values[b]			Extrapolated Values for Chronic Exposures				
						Toxicological Benchmarks			
Chemical - exp. animal	Wildlife	LOAEL (mg/kg/day)	NOAEL (mg/kg/day)	Endpoint	NOAEL (mg/kg/day)	Diet[e] (mg/kg food)	Water[f,e] (mg/L)	Final Water Crit. (mg/L)[g,h]	References (LOAEL/NOAEL)
Asbestos - rat			500	reproduction	50[c,d]				ATSDR ,1990a
	short-tailed shrew				141	741	938		
	white-footed mouse				129	764	878		
	cottontail rabbit				35	404	357		
	mink				31	484	325		
	red fox				20	392	237		
	whitetail deer				9	320	139		
Barium - rat		5.1 (16 mo)	0.51 (16mo)	cardiovascular	0.51				Perry et al., 1983
	short-tailed shrew				1.44	7.6	9.6		
	white-footed mouse				1.31	7.8	9.0		
	cottontail rabbit				0.36	4.1	3.6		
	mink				0.32	4.9	3.3		
	red fox				0.20	4.0	2.4		
	whitetail deer				0.09	3.3	1.4		

Table 12. Toxicological benchmarks for selected mammalian wildlife species[a]									
		Experimental Values[b]			Extrapolated Values for Chronic Exposures				
						Toxicological Benchmarks			
Chemical - exp. animal	Wildlife	LOAEL (mg/kg/day)	NOAEL (mg/kg/day)	Endpoint	NOAEL (mg/kg/day)	Diet[c] (mg/kg food)	Water[d] (mg/L)	Final Water Crit. (mg/L)[e]	References (LOAEL/NOAEL)
Benzene - rat		25 (103 wk)		lympho-cytopenia	2.5[f]				Huff et al., 1989
	short-tailed shrew				7.1	37	47		
	white-footed mouse				6.4	38	44		
	cottontail rabbit				1.8	20	18		
	mink				1.5	24	16	1.0-2.9	
	red fox				0.97	19	12		
	whitetail deer				0.46	16	6.9		
Benzo[a]pyrene - rat		10		reproduction	0.01[f,g]				Mackenzie and Angevine, 1981
	short-tailed shrew				0.013	0.066	0.083		
	white-footed mouse				0.011	0.068	0.078		
	cottontail rabbit				0.003	0.036	0.032		
	mink				0.0028	0.043	0.029	74 pg/L	
	red fox				0.0017	0.035	0.021		
	whitetail deer				0.0008	0.028	0.012		

Table 12. Toxicological benchmarks for selected mammalian wildlife species[a]									
		Experimental Values[b]			Extrapolated Values for Chronic Exposures				
					NOAEL (mg/kg/day)	Toxicological Benchmarks			
Chemical - exp. animal	Wildlife	LOAEL (mg/kg/day)	NOAEL (mg/kg/day)	Endpoint		Diet[c] (mg/kg food)	Water[c,d] (mg/L)	Final Water Crit. (mg/L)[c,e]	References (LOAEL/NOAEL)
Beryllium - rat		443 (83 d)	0.54 (1126 d)	bone; wt. loss	0.54				Businco, 1940/ Schroeder and Mitchener, 1975
	short-tailed shrew				1.53	8.00	10.13		
	white-footed mouse				1.39	8.26	9.48		
	cottontail rabbit				0.38	4.36	3.86		
	mink				0.33	5.23	3.51		
	red fox				0.21	4.23	2.55		
	whitetail deer				0.09	3.46	1.50		
Di-N-butylphthalate - mouse			423 (105 d)	reproduction	42.3[f]				Lamb et al., 1987
	short-tailed shrew				53.2	278.8	352.9		
	white-footed mouse				48.4	287.5	330.1		
	cottontail rabbit				13.3	152.0	134.3		
	mink				11.6	181.9	122.3	0.08-13.9	
	red fox				7.46	147.4	88.9		
	whitetail deer				3.4	120.2	52.3		

Table 12. Toxicological benchmarks for selected mammalian wildlife species[a]

		Experimental Values[b]			Extrapolated Values for Chronic Exposures				
					NOAEL (mg/kg/day)	Toxicological Benchmarks			
Chemical - exp. animal	Wildlife	LOAEL (mg/kg/day)	NOAEL (mg/kg/day)	Endpoint		Diet[(3)] (mg/kg food)	Water[(3)] (mg/L)	Final Water Crit. (mg/L)[(4,5)]	References (LOAEL/NOAEL)
Carbon tetrachloride - rat		10 (12 wk)	0.71 (12 wk)	liver, necrosis	0.071[(2)]	0.91	0.51		Bruckner et al., 1986
	short-tailed shrew				0.201	1.05	1.33		
	white-footed mouse				0.183	1.09	1.25		
	cottontail rabbit				0.050	0.57	0.51		
	mink				0.044	0.69	0.46	0.008-0.20	
	red fox				0.028	0.56	0.34		
	whitetail deer				0.013	0.45	0.20		
Chloroform - rat		90 (78 wk)		kidney, testis	9[(2,7)]	115	64		Reuber, 1979
	short-tailed shrew				25	133	169		
	white-footed mouse				23	138	158		
Chloroform - dog		12.9 (7.5 yr)		liver, fatty cysts	1.29[(2,6)]				Heywood et al., 1979
	cottontail rabbit				2.98	34	30		
	mink				2.61	41	27	2.01-2.49	
	red fox				1.65	33	20		
	whitetail deer				0.77	27	12		

Table 12. Toxicological benchmarks for selected mammalian wildlife species[a]										
		Experimental Values[b]			Extrapolated Values for Chronic Exposures					
					NOAEL (mg/kg/day)	Toxicological Benchmarks				
Chemical - exp. animal	Wildlife	LOAEL (mg/kg/day)	NOAEL (mg/kg/day)	Endpoint		Diet[c] (mg/kg food)	Water[d] (mg/L)	Final Water Crit. (mg/L)[e]	References (LOAEL/NOAEL)
Chromium VI -rat			2.4 (2 yr)		2.4				Mackenzie et al., 1958
	short-tailed shrew				6.79	36	45		
	white-footed mouse				6.17	37	42		
	cottontail rabbit				1.70	19	17		
	mink				1.48	23	16		
	red fox				0.94	19	11		
	whitetail deer				0.44	15	7		
Cyanide - rat			10.8 (104 wk)		10.8				Howard and Hanzal, 1955
	short-tailed shrew				30.5	160	203		
	white-footed mouse				27.8	165	190		
	cottontail rabbit				7.6	87	77		
	mink				6.7	105	70	1.4-30	
	red fox				4.2	85	51		
	whitetail deer				2.0	69	30		

Table 12. Toxicological benchmarks for selected mammalian wildlife species[a]

Chemical - exp. animal	Wildlife	Experimental Values[b] LOAEL (mg/kg/day)	Experimental Values[b] NOAEL (mg/kg/day)	Experimental Values[b] Endpoint	Extrapolated Values for Chronic Exposures: NOAEL (mg/kg/day)	Toxicological Benchmarks: Diet[9] (mg/kg food)	Toxicological Benchmarks: Water[18] (mg/L)	Toxicological Benchmarks: Final Water Crit. (mg/L)[16,e]	References (LOAEL/NOAEL)
Copper cyanide - rat			5 (90 d)		0.5[22]				EPA, 1986d
	short-tailed shrew				1.4	7.41	9.38		
	white-footed mouse				1.3	7.64	8.78		
	cottontail rabbit				0.4	4.04	3.57		
	mink				0.3	4.84	3.25		
	red fox				0.19	3.92	2.37		
	whitetail deer				0.09	3.20	1.39		
Copper gluconate - mouse		1.7 (lifetime)		longevity	0.17[21,22]				Massie and Aiello, 1984
	short-tailed shrew				0.21	1.12	1.42		
	white-footed mouse				0.19	1.16	1.33		
	cottontail rabbit				0.05	0.61	0.54		
	mink				0.048	0.73	0.49		
	red fox				0.029	0.59	0.36		
	whitetail deer				0.014	0.48	0.21		

Table 12. Toxicological benchmarks for selected mammalian wildlife species[a]									
		Experimental Values[b]			Extrapolated Values for Chronic Exposures				
					NOAEL (mg/kg/day)	Toxicological Benchmarks			
Chemical - exp. animal	Wildlife	LOAEL (mg/kg/day)	NOAEL (mg/kg/day)	Endpoint		Diet[c] (mg/kg food)	Water[d] (mg/L)	Final Water Crit. (mg/L)[e]	References (LOAEL/NOAEL)
Copper sulphate - rat			14 (4 wk)	growth; food consumption	1.4[illegible]				Boyden et al., 1938
	short-tailed shrew				3.9	20.8	26.3		
	white-footed mouse				3.6	21.4	24.6		
	cottontail rabbit				0.99	11.3	10.0		
	mink				0.87	13.5	9.1		
	red fox				0.55	10.9	6.6		
	whitetail deer				0.26	8.9	3.9		
1,2-Dichloroethane - rat (inhalation study)			7.4 (8 mo)		0.74[illegible]				Heppel et al., 1946
	short-tailed shrew				2.09	11.0	13.9		
	white-footed mouse				1.90	11.3	12.9		
	cottontail rabbit				0.52	5.9	5.3		
	mink				0.46	7.2	4.8		
	red fox				0.29	5.8	3.5		
	whitetail deer				0.14	4.7	2.1		

Table 12. Toxicological benchmarks for selected mammalian wildlife species[a]									
		Experimental Values[b]			Extrapolated Values for Chronic Exposures				
						Toxicological Benchmarks			
Chemical - exp. animal	Wildlife	LOAEL (mg/kg/day)	NOAEL (mg/kg/day)	Endpoint	NOAEL (mg/kg/day)	Diet[n] (mg/kg food)	Water[m,n] (mg/L)	Final Water Crit. (mg/L)[n,o,r]	References (LOAEL/NOAEL)
1,1-Dichloroethylene - rat		9 (2 yr)		liver.hist.	0.9[c,n]				Quast et al., 1983
	short-tailed shrew				2.54	13.3	16.9		
	white-footed mouse				2.31	13.8	15.8		
	cottontail rabbit				0.64	7.3	6.4		
	mink				0.56	8.7	5.9	0.34-1.15	
	red fox				0.35	7.1	4.3		
	whitetail deer				0.16	5.8	2.5		
1,2-Dichloroethylene, mixed isomers - rat		500 mg/L (2yr)			7.0[c,n]				Quast et al., 1983
	short-tailed shrew				110.3	578	732		
	white-footed mouse				100.3	596	685		
	cottontail rabbit				27.6	315	279		
	mink				24.1	377	254		
	red fox				15.3	306	185		
	whitetail deer				7.1	250	109		

Table 12. Toxicological benchmarks for selected mammalian wildlife species[a]									
		Experimental Values[b]			Extrapolated Values for Chronic Exposures				
					NOAEL (mg/kg/day)	Toxicological Benchmarks			
Chemical - exp. animal	Wildlife	LOAEL (mg/kg/day)	NOAEL (mg/kg/day)	Endpoint		Diet[c] (mg/kg food)	Water[c,d] (mg/L)	Final Water Crit. (mg/L)[c,d,e]	References (LOAEL/NOAEL)
Ethanol - mouse		5500 (gest.)			550[a,e]				
	short-tailed shrew				691	3626	4589		
	white-footed mouse				629	3738	4292		
Ethanol - rabbit		3.945 (gest.)			394[a,e]				
	cottontail rabbit				612	6993	6183		
	whitetail deer				159	5538	2411		
Ethanol - dog		21,600 (gest.)			2,160[a,e]				
	red fox				2766	55384	33427		
	mink				4371	68375	45980		
Ethyl acetate - rat		3600 (90 days)	900 (90 days)	wt. loss	90[c,b]				EPA, 1986e
	short-tailed shrew				255	1335	1689		
	white-footed mouse				231	1376	1580		
	cottontail rabbit				64	727	643		
	mink				56	871	586		
	red fox				35	705	426		
	whitetail deer				16	576	251		

Table 12. Toxicological benchmarks for selected mammalian wildlife species[a]

Chemical - exp. animal	Wildlife	Experimental Values[b] LOAEL (mg/kg/day)	NOAEL (mg/kg/day)	Endpoint	Extrapolated Values for Chronic Exposures NOAEL (mg/kg/day)	Toxicological Benchmarks Diet[d] (mg/kg food)	Water[e] (mg/L)	Final Water Crit. (mg/L)[f]	References (LOAEL/NOAEL)
Di-2-ethylhexylphthalate - mouse			14.1 (105 days)	reproduction	1.41[c]				Lamb et al., 1987
	short-tailed shrew				1.77	9.28	11.75		
	white-footed mouse				1.61	9.57	10.99		
	cottontail rabbit				0.44	5.03	4.44		
	mink				0.39	6.1	4.1	0.0004-79	
	red fox				0.25	5.01	3.02		
	whitetail deer				0.11	3.84	1.67		
1,2,3,6,7,8 Hexachlorodibenzofuran - rat			0.96 ug/kg/day (13 wk)	wt. loss; blood chem.	0.096[c] ug/kg/day				Poiger et al., 1989
	short-tailed shrew				0.27	1.42 ug/kg	1.80 ug/L		
	white-footed mouse				0.25	1.47 ug/kg	1.69 ug/L		
	cottontail rabbit				0.07	0.78 ug/kg	0.69 ug/L		
	mink				0.06	0.93 ug/kg	0.62 ug/L		
	red fox				0.04	0.75 ug/kg	0.45 ug/L		
	whitetail deer				0.02	0.61 ug/kg	0.27 ug/L		

Table 12. Toxicological benchmarks for selected mammalian wildlife species[a]									
		Experimental Values[b]			Extrapolated Values for Chronic Exposures				
					NOAEL (mg/kg/day)	Toxicological Benchmarks			
Chemical - exp. animal	Wildlife	LOAEL (mg/kg/day)	NOAEL (mg/kg/day)	Endpoint		Diet[c] (mg/kg food)	Water[c,d] (mg/L)	Final Water Crit. (mg/L)[c,e]	References (LOAEL/NOAEL)
Lead acetate - rat		50 ppm (2 yr)	10 ppm (2 yr)		0.78				Azar et al., 1973
	short-tailed shrew				2.21	11.57	14.64		
	white-footed mouse				2.01	11.92	13.69		
	cottontail rabbit				0.55	6.30	5.57		
	mink				0.48	7.55	5.07		
	red fox				0.31	6.11	3.69		
	whitetail deer				0.14	4.99	2.17		
Manganese - human			0.14		0.14				Schroeder et al., 1966
	short-tailed shrew				2.27	11.93	15.10		
	white-footed mouse				2.07	12.30	14.12		
	cottontail rabbit				0.57	6.50	5.75		
	mink				0.50	7.78	5.23		
	red fox				0.31	6.30	3.80		
	whitetail deer				0.15	5.15	2.24		

Table 12. Toxicological benchmarks for selected mammalian wildlife species[a]									
		Experimental Values[b]			Extrapolated Values for Chronic Exposures				
					NOAEL (mg/kg/day)	Toxicological Benchmarks			
Chemical - exp. animal	Wildlife	LOAEL (mg/kg/day)	NOAEL (mg/kg/day)	Endpoint		Diet[c] (mg/kg food)	Water[c,e] (mg/L)	Final Water Crit. (mg/L)[c,d,e]	References (LOAEL/NOAEL)
Mercuric chloride - rat		0.64 (39 wk)		immune syst. kidney	0.0064[c,1,2b]				Knoflach et al., 1986
	short-tailed shrew				0.018	0.095	0.120		
	white-footed mouse				0.016	0.098	0.112		
	cottontail rabbit				0.0045	0.052	0.046		
	mink				0.0039	0.062	0.042		
	red fox				0.0025	0.050	0.030		
	whitetail deer				0.0012	0.041	0.018		
Mercuric sulfide - mouse			13.3		13.3				Revis et al., 1989
	short-tailed shrew				16.7	87.68	110.96		
	white-footed mouse				15.2	90.39	103.78		
	cottontail rabbit				4.2	47.77	42.23		
	mink				3.7	57.21	38.47		
	red fox				2.3	46.34	27.97		
	white.ail deer				1.1	37.83	16.47		

Table 12. Toxicological benchmarks for selected mammalian wildlife species[a]									
		Experimental Values[b]			Extrapolated Values for Chronic Exposures				
					NOAEL (mg/kg/day)	Toxicological Benchmarks			
Chemical - exp. animal	Wildlife	LOAEL (mg/kg/day)	NOAEL (mg/kg/day)	Endpoint		Diet[c] (mg/kg food)	Water[c,d] (mg/L)	Final Water Crit. (mg/L)[c,d,e]	References (LOAEL/NOAEL)
Mercury, methyl - rat			0.024 (3 gen)	reproduction	0.024				Verschueren et al., 1976
	short-tailed shrew				0.067	0.36	0.45		
	white-footed mouse				0.062	0.37	0.42		
	cottontail rabbit				0.017	0.19	0.17		
	whitetail deer				0.004	0.15	0.07		
Mercury, methyl - mink			0.07 (93 d)	wt.loss, ataxia	0.007[c,b]	0.11	0.07		Wobeser et al., 1975
	red fox				0.004	0.09	0.05		
Methanol - rat		2500 (90 d)	500 (90 d)	blood chem.	50[c,b]				EPA, 1986f
	short-tailed shrew				141	741	938		
	white-footed mouse				129	764	878		
	cottontail rabbit				35	404	357		
	mink				31	484	325	234-297	
	red fox				20	392	237		
	whitetail deer				9	320	139		

Table 12. Toxicological benchmarks for selected mammalian wildlife species[a]									
		Experimental Values[b]			Extrapolated Values for Chronic Exposures				
					NOAEL (mg/kg/day)	Toxicological Benchmarks			
Chemical - exp. animal	Wildlife	LOAEL (mg/kg/day)	NOAEL (mg/kg/day)	Endpoint		Diet[c] (mg/kg food)	Water[c,d] (mg/L)	Final Water Crit. (mg/L)[illegible]	References (LOAEL/NOAEL)
Methylene chloride - rat		52.58 (2 yr)	5.85 (2 yr)	liver; histology	5.85				NCA, 1982
	short-tailed shrew				16.54	86.75	109.79		
	white-footed mouse				15.04	89.43	102.69		
	cottontail rabbit				4.137	47.27	41.79		
	mink				3.62	56.61	38.07	0.69-8.7	
	red fox				2.29	45.85	27.68		
	whitetail deer				1.07	37.43	16.30		
Methyl ethyl ketone - rat (inhalation data)			92 (12 wk)		9.2[illegible]				Labelle and Brieger, 1955
	short-tailed shrew				26	136.4	172.7		
	white-footed mouse				23.7	140.6	161.5		
	cottontail rabbit				6.5	74.3	65.7		
	mink				5.7	89.0	59.9	25.5-56.0	
	red fox				3.6	72.1	43.5		
	whitetail deer				1.7	58.9	25.6		

Table 12. Toxicological benchmarks for selected mammalian wildlife species[a]									
		Experimental Values[b]			Extrapolated Values for Chronic Exposures				
						Toxicological Benchmarks			
Chemical - exp. animal	Wildlife	LOAEL (mg/kg/day)	NOAEL (mg/kg/day)	Endpoint	NOAEL (mg/kg/day)	Diet[d] (mg/kg food)	Water[e,f] (mg/L)	Final Water Crit. (mg/L)[e,g,h]	References (LOAEL/NOAEL)
4-Methyl-2-pentanone (methyl isobutyl ketone) - rat			50 (13 wk)	liver, kidney	5[c,h]				Microbiological Associates, 1986
	short-tailed shrew				14.1	74	94		
	white-footed mouse				12.9	76	88		
	cottontail rabbit				3.6	40	36		
	mink				3.1	48	33	12.1-12.4	
	red fox				1.9	39	24		
	whitetail deer				0.9	32	14		
Nickel sulphate - rat			24.15 (3 gen)	reproduction	24.15				Ambrose et al., 1976
	short-tailed shrew				68.29	358	453		
	white-footed mouse				62.10	369	424		
	cottontail rabbit				17.08	195	173		
	mink				14.94	234	158		
	red fox				9.46	189	114		
	whitetail deer				4.42	155	67		

Table 12. Toxicological benchmarks for selected mammalian wildlife species[a]										
		Experimental Values[b]			Extrapolated Values for Chronic Exposures					
						Toxicological Benchmarks				
Chemical - exp. animal	Wildlife	LOAEL (mg/kg/day)	NOAEL (mg/kg/day)	Endpoint	NOAEL (mg/kg/day)	Diet[c] (mg/kg food)	Water[c,d] (mg/L)	Final Water Crit. (mg/L)[c,d,e]	References (LOAEL/NOAEL)
Nitrate - human		1.8-3.2 (≤ 8 mo)	1.6 (≤ 8 mo)	methemo-globinemia	1.6				Bosch et al., 1950
	short-tailed shrew				25.9	136.33	172.53		
	white-footed mouse				23.6	140.54	161.37		
	cottontail rabbit				6.5	74.28	65.67		
	mink				5.7	88.96	59.82		
	red fox				3.6	72.06	43.49		
	whitetail deer				1.7	58.82	25.61		
PCBs - Aroclor 1254 - white-footed mouse		1.7		reproduction	0.17[c,e]	1.0	1.1		Linzey, 1987
PCBs - Aroclor 1254	cottontail rabbit				0.046	0.67	0.46		
	short-tailed shrew				0.186	0.98	1.24		
PCBs - Aroclor 1254 - mink			0.07	reproduction	0.07	1.0	0.69	0.0005-0.032 ug/L	Aulerich and Ringer, 1977
PCBs - Aroclor 1254	red fox				0.035	0.71	0.43		
PCBs - Aroclor 1254	whitetail deer				0.017	0.59	0.26		

Table 12. Toxicological benchmarks for selected mammalian wildlife species[a]									
		Experimental Values[b]			Extrapolated Values for Chronic Exposures				
					NOAEL (mg/kg/day)	Toxicological Benchmarks			
Chemical - exp. animal	Wildlife	LOAEL (mg/kg/day)	NOAEL (mg/kg/day)	Endpoint		Diet[c] (mg/kg food)	Water[c,d] (mg/L)	Final Water Crit. (mg/L)[c,e]	References (LOAEL/NOAEL)
2,3,4,7,8 - Pentachlorodibenzofuran - rat			0.096 ug/kg/d (13 wk)	wt. loss blood chem.	0.0096[a,b] ug/kg/day				Poiger et al., 1989
	short-tailed shrew				0.027	0.142 ug/kg	0.180 ug/L		
	white-footed mouse				0.025	0.147 ug/kg	0.169 ug/L		
	cottontail rabbit				0.007	0.078 ug/kg	0.069 ug/L		
	mink				0.006	0.093 ug/kg	0.062 ug/L		
	red fox				0.0038	0.075 ug/kg	0.045 ug/L		
	whitetail deer				0.0018	0.062 ug/kg	0.027 ug/L		
1,2,3,4,8 Pentachlorodibenzofuran - rat			290 ug/kg/day (13 wk)	wt. loss blood chem.	29[a,b] ug/kg/day				
	short-tailed shrew				81.9	429 ug/kg	544 ug/L		Poiger et al., 1989
	white-footed mouse				74.5	443 ug/kg	509 ug/L		
	cottontail rabbit				20.5	234 ug/kg	207 ug/L		
	mink				17.9	280 ug/kg	189 ug/L		
	red fox				11.3	227 ug/kg	137 ug/L		
	whitetail deer				5.3	185 ug/kg	81 ug/L		

Table 12. Toxicological benchmarks for selected mammalian wildlife species[a]									
		Experimental Values[b]			Extrapolated Values for Chronic Exposures				
						Toxicological Benchmarks			
Chemical - exp. animal	Wildlife	LOAEL (mg/kg/day)	NOAEL (mg/kg/day)	Endpoint	NOAEL (mg/kg/day)	Diet[d] (mg/kg food)	Water[e] (mg/L)	Final Water Crit. (mg/L)[f]	References (LOAEL/NOAEL)
1,2,3,7,8 - Pentachlorodibenzofuran - rat			0.96 ug/kg/day (13 wk)	wt. loss blood chem.	0.096[c] ug/kg/day				Poiger et al., 1989
	short-tailed shrew				0.27	1.42 ug/kg	1.80 ug/L		
	white-footed mouse				0.25	1.47 ug/kg	1.69 ug/L		
	cottontail rabbit				0.068	0.77 ug/kg	0.69 ug/L		
	mink				0.059	0.93 ug/kg	0.62 ug/L		
	red fox				0.038	0.75 ug/kg	0.45 ug/L		
	whitetail deer				0.018	0.61 ug/kg	0.27 ug/L		
Selenium (as selenate) - mouse		0.57		reproduction	0.057[c]				Schroeder and Mitchner, 1971
	short-tailed shrew				0.07	0.38	0.48		
	white-footed mouse				0.065	0.39	0.44		
	cottontail rabbit				0.018	0.20	0.18		
	mink				0.016	0.25	0.16		
	red fox				0.01	0.20	0.12		
	whitetail deer				0.005	0.16	0.07		

Table 12. Toxicological benchmarks for selected mammalian wildlife species[a]									
		Experimental Values[b]			Extrapolated Values for Chronic Exposures				
					NOAEL (mg/kg/day)	Toxicological Benchmarks			
Chemical - exp. animal	Wildlife	LOAEL (mg/kg/day)	NOAEL (mg/kg/day)	Endpoint		Diet[a] (mg/kg food)	Water[a] (mg/L)	Final Water Crit. (mg/L)[a]	References (LOAEL/NOAEL)
Strontium (stable) - rat			263.1 (3 yr)	rachitic changes	263.1				Skoryna, 1981
	short-tailed shrew				743	3901	4938		
	white-footed mouse				677	4022	4618		
	cottontail rabbit				186	2126	1879		
	mink				163	2546	1712		
	red fox				103	2062	1245		
	whitetail deer				48	1683	733		
2,3,7,8 - TCDD - rat			0.001 ug/kg/day (3 gen)	reproduction	0.001 ug/kg/day				Murray et al., 1979
	short-tailed shrew				0.0028	0.0148 ug/kg	0.0188 ug/L		
	white-footed mouse				0.0026	0.0153 ug/kg	0.0175 ug/L		
	cottontail rabbit				0.0007	0.0081 ug/kg	0.0072 ug/L		
	mink				0.0006	0.0097 ug/kg	0.0065 ug/L	0.002-0.012pg/L	
	red fox				0.0004	0.0078 ug/kg	0.0047 ug/L		
	whitetail deer				0.00018	0.0063 ug/kg	0.0027 ug/L		

Table 12. Toxicological benchmarks for selected mammalian wildlife species[a]									
		Experimental Values[b]			Extrapolated Values for Chronic Exposures				
					NOAEL (mg/kg/day)	Toxicological Benchmarks			
Chemical - exp. animal	Wildlife	LOAEL (mg/kg/day)	NOAEL (mg/kg/day)	Endpoint		Diet[h] (mg/kg food)	Water[i,h] (mg/L)	Final Water Crit. (mg/L)[m,n,o]	References (LOAEL/NOAEL)
1,1,2,2-Tetrachloroethylene - mouse		300 (78 wk)		liver	30[c,n]				NCI, 1977a
	short-tailed shrew				37.7	198	250		
	white-footed mouse				34.3	204	234		
	cottontail rabbit				9.4	108	95		
	mink				8.3	129	87	0.9-11.4	
	red fox				5.2	105	63		
	whitetail deer				2.4	85	37		
Toluene - rat		446 (13 wk)	223 (13 wk)	inc. organ wt.	22.3[c,l]				NTP, 1989
	short-tailed shrew				63.1	331	419		
	white-footed mouse				57.3	341	391		
	cottontail rabbit				15.8	180	159		
	mink				13.8	216	145	2.7-7.8	
	red fox				8.7	175	105		
	whitetail deer				4.1	143	62		

Table 12. Toxicological benchmarks for selected mammalian wildlife species[a]

Chemical - exp. animal	Wildlife	Experimental Values[b] LOAEL (mg/kg/day)	NOAEL (mg/kg/day)	Endpoint	Extrapolated Values for Chronic Exposures NOAEL (mg/kg/day)	Toxicological Benchmarks Diet[illegible] (mg/kg food)	Water[illegible] (mg/L)	Final Water Crit. (mg/L)[illegible]	References (LOAEL/NOAEL)
1,1,1-Trichloroethane - rat		750 (78 wk)	350 (12 wk)	decr. survival	35[illegible]				NCI, 1977b/Bruckner et al., 1985
	short-tailed shrew				99	519	657		
	white-footed mouse				90	535	614		
	cottontail rabbit				25	283	250		
	mink				22	339	228	7.2-61.4	
	red fox				14	274	166		
	whitetail deer				6.40955	223.95353	98		
Trichloroethylene - rat		150 (2 gen.)	75 (2 gen.)	reproduction	75				NTP, 1986
	short-tailed shrew				212	1112	1408		
	white-footed mouse				193	1147	1317		
	cottontail rabbit				53	606	536		
	mink				46	726	488	16.9-49.6	
	red fox				29	588	355		
	whitetail deer				14	480	209		

Table 12. Toxicological benchmarks for selected mammalian wildlife species[a]

		Experimental Values[b]			Extrapolated Values for Chronic Exposures				
						Toxicological Benchmarks			
Chemical - exp. animal	Wildlife	LOAEL (mg/kg/day)	NOAEL (mg/kg/day)	Endpoint	NOAEL (mg/kg/day)	Diet[c] (mg/kg food)	Water[c,d] (mg/L)	Final Water Crit. (mg/L)[c,e]	References (LOAEL/NOAEL)
Uranium (soluble salts) - rabbit		2.8 (30 days)		kidney, hist.	0.28[d,e]				Maynard and Hodge, 1949
	short-tailed shrew				1.74	9.12	11.54		
	white-footed mouse				1.58	9.40	10.80		
	cottontail rabbit				0.44	4.97	4.39		
	mink				0.38	5.95	4.00		
	red fox				0.24	4.82	2.90		
	whitetail deer				0.11	3.94	1.71		
Vinyl chloride - rat		1.3 (149 wk)	0.13 (149 wk)	decr. survival liver	0.13				Dow Chemical Co., 1984
	short-tailed shrew				0.37	1.93	2.44		
	white-footed mouse				0.33	1.99	2.28		
	cottontail rabbit				0.09	1.05	0.93		
	mink				0.08	1.26	0.85	0.002-0.9 µg/L	
	red fox				0.05	1.02	0.62		
	whitetail deer				0.02	0.83	0.36		

Table 12. Toxicological benchmarks for selected mammalian wildlife species[a]										
		Experimental Values[b]			Extrapolated Values for Chronic Exposures					
					NOAEL (mg/kg/day)	Toxicological Benchmarks				
Chemical - exp. animal	Wildlife	LOAEL (mg/kg/day)	NOAEL (mg/kg/day)	Endpoint		Diet[c] (mg/kg food)	Water[d] (mg/L)	Final Water Crit. (mg/L)[e]	References (LOAEL/NOAEL)
Mixed xylenes - rat			500 (103 wk)	reproduction	500				ATSDR, 1990b
	short-tailed shrew				1414	7415	9384		
	white-footed mouse				1286	7644	8777		
	cottontail rabbit				354	4040	3572		
	mink				310	4839	3254	570	
	red fox				196	3920	2366		
	whitetail deer				92	3200	1393		
Zinc carbonate - rat			97 (37 days)	reproduction	9.7[f]				Kinnamon, 1963
	short-tailed shrew				27.4	144	182		
	white-footed mouse				24.9	148	170		
	cottontail rabbit				6.9	78	69		
	mink				6.0	94	63		
	red fox				3.8	76	46		
	whitetail deer				1.8	62	27		

Table 12. Toxicological benchmarks for selected mammalian wildlife species[a]									
		Experimental Values[b]			Extrapolated Values for Chronic Exposures				
						Toxicological Benchmarks			
Chemical - exp. animal	Wildlife	LOAEL (mg/kg/day)	NOAEL (mg/kg/day)	Endpoint	NOAEL (mg/kg/day)	Diet[b] (mg/kg food)	Water[b] (mg/L)	Final Water Crit. (mg/L)[c]	References (LOAEL/NOAEL)
Zirconium sulphate - mouse		0.7 (lifetime)		longevity	0.07[a]				Schroeder et al., 1968
	short-tailed shrew				0.09	0.46	0.58		
	white-footed mouse				0.08	0.48	0.55		
	cottontail rabbit				0.02	0.25	0.22		
	mink				0.019	0.30	0.20		
	red fox				0.012	0.24	0.15		
	whitetail deer				0.006	0.20	0.09		

[a] Numbers in parentheses refer to equations in text.

[b] Dietary concentration in ppm; water concentration in mg/L.

[c] Calculated from Equation 16 using FCM values given in Table 8 and log P and BCF values given in Table 10.

Table 13. Toxicological benchmarks for selected avian wildlife species[a]									
		Experimental Values[b]			Extrapolated Values for Chronic Exposures				
					NOAEL (mg/kg/day)	Toxicological Benchmarks			
Chemical - exp. animal	Wildlife	LOAEL (mg/kg/day)	NOAEL (mg/kg/day)	Endpoint		Diet[c] (mg/kg food)	Water[c,d] (mg/L)	Final Water Crit. (mg/L)[c,d,e]	References (LOAEL/NOAEL)
Chlordane - redwinged blackbird			2.13 (84 days)	mortality	2.13				
	American Robin				2.11	9.7	14.6		Stickel et al., 1983
	Woodcock				1.47	14.3	14.6		
	Wild Turkey				0.48	15.3	14.6		
	Belted Kingfisher				1.62	14.3	14.6	0.17 ug/L	
	Great Blue Heron				0.64	15.0	14.6	0.17 ug/L	
	Barred Owl				0.96	14.7	14.6		
	Cooper's Hawk				1.13	14.6	14.6		
	Red-Tailed Hawk				0.83	14.8	14.6		
Chrome alum ($CrK(SO_4)_2$ - black duck			2.7 (10 mo)	reproduction	2.7				Haseltine et al., unpubl. data
	American Robin				6.77	32.66	49.25		(from Eisler, 1986)
	Woodcock				4.96	48.47	49.25		
	Wild Turkey				1.63	51.67	49.26		
	Belted Kingfisher				5.46	48.18	49.27		
	Great Blue Heron				2.18	50.82	49.26		
	Barred Owl				3.24	49.66	49.26		
	Cooper's Hawk				3.81	49.19	49.25		
	Red-Tailed Hawk				2.79	50.09	49.26		

Table 13. Toxicological benchmarks for selected avian wildlife species[a]									
		Experimental Values[b]			Extrapolated Values for Chronic Exposures				
					NOAEL (mg/kg/day)	Toxicological Benchmarks			
Chemical - exp. animal	Wildlife	LOAEL (mg/kg/day)	NOAEL (mg/kg/day)	Endpoint		Diet[c] (mg/kg food)	Water[c,d] (mg/L)	Final Water Crit. (mg/L)[c,e]	References (LOAEL/NOAEL)
Copper carbonate - mallard duck			29 (98-101 days)	wt. gain; mortality	29				Pullar, 1940
	American Robin				67.59	325.87	491.42		
	Woodcock				49.49	483.66	491.40		
	Wild Turkey				16.23	515.59	491.54		
	Belted Kingfisher				54.48	480.78	491.62		
	Great Blue Heron				21.75	507.07	491.55		
	Barred Owl				32.37	495.56	491.54		
	Cooper's Hawk				38.05	490.88	491.47		
	Red-Tailed Hawk				27.89	499.85	491.55		
Copper oxide - chicken			22.8 (10 wk)	wt.gain; mortality	22.8				Mehring et al., 1960
	American Robin				54.50	262.79	396.29		
	Woodcock				39.91	390.04	396.28		
	Wild Turkey				13.08	415.78	396.39		
	Belted Kingfisher				43.93	387.71	396.46		
	Great Blue Heron				17.54	408.92	396.39		
	Barred Owl				26.10	399.63	396.39		
	Cooper's Hawk				30.69	395.86	396.34		
	Red-Tailed Hawk				22.49	403.09	396.39		

Table 13. Toxicological benchmarks for selected avian wildlife species[a]									
		Experimental Values[b]			Extrapolated Values for Chronic Exposures				
					NOAEL (mg/kg/day)	Toxicological Benchmarks			
Chemical - exp. animal	Wildlife	LOAEL (mg/kg/day)	NOAEL (mg/kg/day)	Endpoint		Diet[c,d] (mg/kg food)	Water[c,e] (mg/L)	Final Water Crit. (mg/L)[c,d,e]	References (LOAEL/NOAEL)
Di-N-butylphthalate - ring dove		1.11 (4 wk)		reproduction	0.0111(21, 22)				Peakall, 1974
	American Robin				0.0139	0.067	0.102		
	Woodcock				0.0102	0.100	0.102		
	Wild Turkey				0.0034	0.107	0.102		
	Belted Kingfisher				0.0113	0.099	0.102		
	Great Blue Heron				0.0045	0.105	0.102		
	Barred Owl				0.0067	0.103	0.102		
	Cooper's Hawk				0.0079	0.102	0.102		
	Red-Tailed Hawk				0.0058	0.103	0.102		
DDT and metabolites - brown pelican			0.028 (>1 yr)	reproduction	0.028				Anderson et al., 1975
	American Robin				0.098	0.48	0.72		
	Woodcock				0.072	0.71	0.72		
	Wild Turkey				0.024	0.75	0.72		
	Belted Kingfisher				0.080	0.70	0.72	188-545 pg/L	
	Great Blue Heron				0.032	0.74	0.72	200-575 pg/L	
	Barred Owl				0.047	0.72	0.72		
	Cooper's Hawk				0.056	0.72	0.72		
	Red-Tailed Hawk				0.041	0.72	0.72		

Table 13. Toxicological benchmarks for selected avian wildlife species[a]									
		Experimental Values[b]			Extrapolated Values for Chronic Exposures				
					NOAEL (mg/kg/day)	Toxicological Benchmarks			
Chemical - exp. animal	Wildlife	LOAEL (mg/kg/day)	NOAEL (mg/kg/day)	Endpoint		Diet[c] (mg/kg food)	Water[c,d] (mg/L)	Final Water Crit. (mg/L)[e,f]	References (LOAEL/NOAEL)
Di-2-ethylhexylphthalate - ring dove			1.11 (4 wk)	reproduction	0.111[c,e]				Peakall, 1974
	American Robin				0.139	0.67	1.02		
	Woodcock				0.102	1.00	1.02		
	Wild Turkey				0.034	1.07	1.02		
	Belted Kingfisher				0.113	0.99	1.02	3.3x10⁻³-0.008	
	Great Blue Heron				0.045	1.05	1.02	4.5x10⁻³-0.008	
	Barred Owl				0.067	1.03	1.02		
	Cooper's Hawk				0.079	1.02	1.02		
	Red-Tailed Hawk				0.058	1.03	1.02		
Mercury, methyl - mallard		0.064 (3 gen)		reproduction	0.0064[c,d]				Heinz, 1979
	American Robin				0.015	0.072	0.108		
	Woodcock				0.011	0.106	0.108		
	Wild Turkey				0.0036	0.113	0.108		
	Belted Kingfisher				0.012	0.106	0.108		
	Great Blue Heron				0.005	0.111	0.108		
	Barred Owl				0.007	0.109	0.108		
	Cooper's Hawk				0.008	0.108	0.108		
	Red-Tailed Hawk				0.006	0.110	0.108		

Table 13. Toxicological benchmarks for selected avian wildlife species[a]									
		Experimental Values[b]			Extrapolated Values for Chronic Exposures				
					NOAEL (mg/kg/day)	Toxicological Benchmarks			
Chemical - exp. animal	Wildlife	LOAEL (mg/kg/day)	NOAEL (mg/kg/day)	Endpoint		Diet[*] (mg/kg food)	Water[**] (mg/L)	Final Water Crit. (mg/L)[***]	References (LOAEL/NOAEL)
Nickel sulphate/nickel acetate - chicken			21.4 (4 wk)	wt. gain; metabolism	2.14[(22)]				Weber and Reid, 1968
	American Robin				4.11	19.81	29.88		
	Woodcock				3.01	29.41	29.88		
	Wild Turkey				0.99	31.35	29.88		
	Belted Kingfisher				3.31	29.23	29.89	6.5x10^{5}-0.0012	
	Great Blue Heron				1.32	30.83	29.88	6.7x10^{5}-0.0013	
	Barred Owl				1.97	30.13	29.88		
	Cooper's Hawk				2.31	29.84	29.88		
	Red-Tailed Hawk				1.70	30.39	29.89		
PCB (Aroclor 1254) - ring-necked pheasant			1.57 (17 wk)	reproduction	1.57				Dahlgren et al., 1972
	American Robin				3.82	18.4	27.7		
	Woodcock				2.79	27.3	27.7		
	Wild Turkey				0.92	29.1	27.7		
	Belted Kingfisher				3.08	27.1	27.7	0.012-0.8 ug/L	
	Great Blue Heron				1.23	28.6	27.7	0.012-0.8 ug/L	
	Barred Owl				1.83	28.0	27.7		
	Cooper's Hawk				2.15	27.7	27.7		
	Red-Tailed Hawk				1.57	28.2	27.7		

Table 13. Toxicological benchmarks for selected avian wildlife species[a]									
		Experimental Values[b]			Extrapolated Values for Chronic Exposures				
					NOAEL (mg/kg/day)	Toxicological Benchmarks			
Chemical - exp. animal	Wildlife	LOAEL (mg/kg/day)	NOAEL (mg/kg/day)	Endpoint		Diet[illegible] (mg/kg food)	Water[illegible] (mg/L)	Final Water Crit. (mg/L)[illegible]	References (LOAEL/NOAEL)
Sodium selenite - mallard duck			1 (70 d)	reproduction	0.1[illegible]				Heinz et al., 1987
	American Robin				0.23	1.12	1.69		
	Woodcock				0.17	1.67	1.69		
	Wild Turkey				0.06	1.78	1.69		
	Belted Kingfisher				0.19	1.66	1.70		
	Great Blue Heron				0.08	1.75	1.69		
	Barred Owl				0.11	1.71	1.69		
	Cooper's Hawk				0.13	1.69	1.69		
	Red-Tailed Hawk				0.10	1.72	1.69		
Selanomethionine - mallard duck			0.4 (70 d)	reproduction	0.04[illegible]				Heinz et al., 1989
	American Robin				0.09	0.45	0.68		
	Woodcock				0.07	0.67	0.68		
	Wild Turkey				0.02	0.71	0.68		
	Belted Kingfisher				0.08	0.66	0.68		
	Great Blue Heron				0.03	0.70	0.68		
	Barred Owl				0.04	0.68	0.68		
	Cooper's Hawk				0.05	0.68	0.68		
	Red-Tailed Hawk				0.04	0.69	0.68		

Table 13. Toxicological benchmarks for selected avian wildlife species[a]									
		Experimental Values[b]			Extrapolated Values for Chronic Exposures				
					NOAEL (mg/kg/day)	Toxicological Benchmarks			
Chemical - exp. animal	Wildlife	LOAEL (mg/kg/day)	NOAEL (mg/kg/day)	Endpoint		Diet[a] (mg/kg food)	Water[a,b] (mg/L)	Final Water Crit. (mg/L)[***]	References (LOAEL/NOAEL)
2,3,7,8-TCDD - ring-necked pheasant			0.014 ug/kg/day (10 wk)	reproduction	0.014 ug/kg/d				Nosek et al., 1992
	American Robin				0.034 ug/kg/d	0.16 ug/kg	0.24 ug/L		
	Woodcock			.	0.025 ug/kg/d	0.24 ug/kg	0.24 ug/L		
	Wild Turkey				0.008 ug/kg/d	0.26 ug/kg	0.24 ug/L		
	Belted Kingfisher				0.027 ug/kg/d	0.24 ug/kg	0.24 ug/L	0.001-0.3 pg/L	
	Great Blue Heron				0.011 ug/kg/d	0.25 ug/kg	0.24 ug/L	0.04-0.3 pg/L	
	Barred Owl				0.016 ug/kg/d	0.25 ug/kg	0.24 ug/L		
	Cooper's Hawk				0.019 ug/kg/d	0.25 ug/kg	0.24 ug/L		
	Red-Tailed Hawk				0.014 ug/kg/d	0.25 ug/kg	0.24 ug/L		
2,3,7,8-TCDF - chicken		0.1ug/kg/day (21 d)		wt. gain; mortality	0.001[21, 22] ug/kg/d				McKinney et al., 1976
	American Robin				0.001ug/kg/d	0.006 ug/kg	0.0097 ug/L		
	Woodcock				0.001 ug/kg/d	0.009 ug/kg	0.0097 ug/L		
	Wild Turkey				0.0003 ug/kg/d	0.01 ug/kg	0.0097 ug/L		
	Belted Kingfisher				0.001 ug/kg/d	0.009 ug/kg	0.0097 ug/L		
	Great Blue Heron				0.0004 ug/kg/d	0.01 ug/kg	0.0097 ug/L		
	Barred Owl				0.0006 ug/kg/d	0.01 ug/kg	0.0097 ug/L		
	Cooper's Hawk				0.0008 ug/kg/d	0.01 ug/kg	0.0097 ug/L		
	Red-Tailed Hawk				0.0006 ug/kg/d	0.01 ug/kg	0.0097 ug/L		

Table 13. Toxicological benchmarks for selected avian wildlife species[a]

		Experimental Values[b]			Extrapolated Values for Chronic Exposures				
						Toxicological Benchmarks			
Chemical - exp. animal	Wildlife	LOAEL (mg/kg/day)	NOAEL (mg/kg/day)	Endpoint	NOAEL (mg/kg/day)	Diet[(3)] (mg/kg food)	Water[(4)] (mg/L)	Final Water Crit. (mg/L)[(5),c]	References (LOAEL/NOAEL)
Uranium (depleted, metallic) - black duck			86 (6 wk)	liver, kidney, mortality	8.6[(22)]				Haseltine and Sileo, 1983
	American Robin				21.6	104	156		
	Woodcock				15.8	154	156		
	Wild Turkey				5.2	165	156		
	Belted Kingfisher				17.4	153	156		
	Great Blue Heron				6.9	162	156		
	Barred Owl				10.3	158	156		
	Cooper's Hawk				12.1	157	156		
	Red-Tailed Hawk				8.9	160	156		
Zinc carbonate - mallard		170 (60 d)		blood chem.; mortality	1.7[(21, 22)]				Gasaway and Buss, 1972
	American Robin				4.1	19.6	29.5		
	Woodcock				3.0	29.1	29.5		
	Wild Turkey				1.0	31.0	29.5		
	Belted Kingfisher				3.3	28.9	29.5		
	Great Blue Heron				1.3	30.5	29.5		
	Barred Owl				1.9	29.8	29.5		
	Cooper's Hawk				2.3	29.5	29.5		
	Red-Tailed Hawk				1.7	30.0	29.5		

[a] Numbers in parentheses refer to equations in text.

[b] Dietary concentration in mg/kg food; water concentration in mg/L.

[c] Calculated from Equation 16 using FCM values given in Table 8 and log P and BCF values given in Table 10.

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APPENDIX A

Selected Toxicity Data for Avian and Mammalian Wildlife

Selected toxicity data for avian and mammalian wildlife[a]						
		LOAEL		NOAEL	Acute or Lethal Dose/Conc.[b]	LD_{50} or LC_{50}
Chemical	Species	Dose or Conc.[b]	Effect	Dose or Conc.[b]		
Acrolein	mallard duck				3.3	9.11
2-Aminobutane base	rat					350
2-Aminobutane acetate	rat					480
2-Aminobutane hydrochloride	rat					430
4-Aminopyridine	house sparrow herring gull pigeon				1.4 4.5 4	
Antimony	bobwhite quail			60000 (6 wk)		
Antimony potassium tartráte	albino rat				300	494
Aroclor 1016	ferret			20 ppm (9 mo)		
Aroclor 1016	mink	20 ppm (9 mo)	reproduction		20 ppm	
Aroclor 1221	bobwhite quail		30% mortality		6000 ppm (5 d)	
Aroclor 1221	Japanese quail					>6000 ppm (5 d)
Aroclor 1221	ring-necked pheasant				>4000 ppm (5 d)	
Aroclor 1232	bobwhite quail					3002 ppm (5 d)
Aroclor 1232	Japanese quail					>5000 ppm (5 d)
Aroclor 1232	ring-necked pheasant					3146 ppm (5 d)

Selected toxicity data for avian and mammalian wildlife[a]						
Chemical	Species	LOAEL		NOAEL	Acute or Lethal Dose/Conc.[b]	LD_{50} or LC_{50}
		Dose or Conc.[b]	Effect	Dose or Conc.[b]		
Aroclor 1242	ferret	20 ppm (9 mo)	reproduction		20 ppm	
Aroclor 1242	mink	5 ppm (9 mo)	reproduction		10 ppm (9 mo)	315-833
Aroclor 1242	Japanese quail	321.5 ppm (21 d)	reproduction			
Aroclor 1242	Japanese quail	10 ppm (45 d)	reprod.			
Aroclor 1248	screech owl			3 ppm (18 mo)		
Aroclor 1248	chicken	10 ppm (8 wk)	reprod.	1 ppm (8 wk)		
Aroclor 1254	raccoon	50 mg/kg (8 d)	physiology			
Aroclor 1254	cottontail rabbit	10 ppm (12 wk)	wt. loss			
Aroclor 1254	white-footed mouse	10 ppm (__)	reprod.; decr. rurv. of pups			
Aroclor 1254	quail	50 ppm (14 wk)	reprod.			
Aroclor 1254	Japanese quail	78.1 ppm (21 d)	reproduction			
Aroclor 1254	Japanese quail			20 ppm (8 wk)		
Aroclor 1254	Japanese quail	5 ppm (12 wk)	physiol.			
Aroclor 1254	mourning dove	40 ppm (42 d)	metabolism			
Aroclor 1254	ring dove	10 ppm	reprod.			
Aroclor 1254	pheasant	12.5 mg (1x/wk, 17 wk)				

Selected toxicity data for avian and mammalian wildlife[a]						
Chemical	Species	LOAEL		NOAEL	Acute or Lethal Dose/Conc.[b]	LD_{50} or LC_{50}
		Dose or Conc.[b]	Effect	Dose or Conc.[b]		
Aroclor 1260	bobwhite quail	5 ppm (4 mo)	thyroid wt.			
Aroclor 1260	Japanese quail	62.5 ppm (21 d)	reproduction			
Arsanilic acid	rat					216 mg/kg
Cadmium	deer mouse	1 mg/L	infertility			
Cadmium	wood duck	100 ppm (3 mo)	pathology	10 ppm (3 mo)		
Cadmium	black duck	4 ppm (4 mo)	offspring behav.			
Cadmium chloride	mallard duck	20 ppm (30-90 d)	pathol.			
Cadmium succinate	bobwhite quail					1728 ppm (5 d)
Cadmium succinate	Japanese quail					2693 ppm (5 d)
Cadmium succinate	ring-necked pheasant					1411 ppm (5 d)
Cadmium succinate	mallard duck					>5000 ppm (5 d)
Chlordane	bobwhite quail					331 ppm (5 day)
Chlordane	Japanese quail					350 ppm (5 d)
Chlordane	Japanese quail	25 ppm (8 d)	reproduction			
Chlordane	ring-necked pheasant					430 ppm (5 d)
Chlordane	mallard duck					858 ppm (5 d)

Selected toxicity data for avian and mammalian wildlife[a]						
Chemical	Species	LOAEL		NOAEL	Acute or Lethal Dose/Conc.[b]	LD_{50} or LC_{50}
		Dose or Conc.[b]	Effect	Dose or Conc.[b]		
Chlormerodrin (as Hg)	rat					82
3-Chloro-p-toluidine HCl	raven					15.4 5.6
"	golden eagle				100 mg/kg	10 mg/kg
3-Chloro-1,2-propanediol	rat		reproduction		10000	
Chromium (trivalent)	black duck (young)	10 ppm	survival			
Chromium - potassium dichromate	Japanese quail		5-d LC_{50}			4400 ppm
2,4,D	deer mouse			3 lb/acre		
p,p'-DDD	pheasant					552
DDD	cowbird	1500 ppm (17 d)	lethal			
DDE	cowbird	1500 ppm (27 d)	lethal			
DDE	Japanese quail	25 ppm (14 wk)	reproduction; liver	5 ppm (12 wk)		
DDE	rat-tailed bat			107 ppm (40 d)		
p,p'-DDE	mallard duck	5 ppm (several mo)	thin egg shells	1 ppm		
p,p'-DDE	black duck	10 ppm (6 mo/yr)	thin egg shells			
p,p'-DDE	pigeon	18 mg/kg (8 wk)			36 (8 wk)	

Selected toxicity data for avian and mammalian wildlife[a]						
Chemical	Species	LOAEL		NOAEL	Acute or Lethal Dose/Conc.[b]	LD_{50} or LC_{50}
		Dose or Conc.[b]	Effect	Dose or Conc.[b]		
DDT	Japanese quail	25 ppm (14 wk)	reproduction			
DDT	Japanese quail	50 ppm (10 wk)	reproduction	5 ppm (10 wk)		
DDT	bobwhite quail	500 ppm (4 mo)	thyroid	50 ppm (4 mo)		
DDT	mallard duck	330 ppm (5 d)	growth			
DDT	mallard duck	50 ppm (6 mo)				
DDT	mallard duck					1869 ppm (5 d)
DDT	house sparrow				1500 ppm (3 d)	
DDT	white-throated sparrow	5 ppm (11 wk)	behav.; physiol.			
DDT	earthworm	5 lb/acre	decr. pop.			
Di-butyl phthalate	mallard duck		5-d lethal conc.		>5000 ppm	
Di-butyl phthalate	ring dove	10 ppm	thin egg shells			
2,4-Dichlorophenyl-p-nitrophenyl ether	rat	100 ppm (97 wk)	reproduction	10 ppm (3 gen.)		2600
"	dog			2000 ppm (2 yr)		
Di(2-ethylhexyl)phthalate	ferret	10,000 ppm (14 mo)	physiol.			
Di(2-ethylhexyl)phthalate	ring dove			10 ppm		
Ferrous sulfate	rat					1187 mg/kg

Selected toxicity data for avian and mammalian wildlife[a]						
Chemical	Species	LOAEL		NOAEL	Acute or Lethal Dose/Conc.[b]	LD_{50} or LC_{50}
		Dose or Conc.[b]	Effect	Dose or Conc.[b]		
Hexachlorobenzene	Japanese quail	20 ppm (90 d)	reproduction			
Hexachlorobenzene	Japanese quail				1 ppm (90 d)	
Hexachlorobenzene	mallard duck		30% mortality		5000 ppm	>5000 ppm
Hexachlorobutadiene	Japanese quail	0.3 ppm (90 d)				
Hexachlorophene	rat	100 ppm (3 gen.)	reproduction	20 ppm (3 gen.)		
Hexamethylphosphoric triamide	rat	2 mg/kg/d (169 d)	reproduction			
Iodine	mule deer	200 UC (1 x/mo. 7 mo)	accum. in thyroid			
Kepone	Japanese quail				200 ppm (240 d)	
Kepone	Japanese quail					
Lead	bobwhite quail			2000 ppm (6 wk)		
Lead acetate	Japanese quail	1 ppm (12 wk)	reproductiion			
Lead acetate	bobwhite quail	1000 ppm (6 wk)	growth			
Lead arsenate	rat					1545 mg/kg
Lead arsonate	Japanese quail					4185 ppm (5 d)
Lead arsonate	ring-necked pheasant					4989 ppm (5 d)

Selected toxicity data for avian and mammalian wildlife[a]						
Chemical	Species	LOAEL		NOAEL	Acute or Lethal Dose/Conc.[b]	LD_{50} or LC_{50}
		Dose or Conc.[b]	Effect	Dose or Conc.[b]		
Lead, tetraethyl	mallard duck				6 mg/kg	
Lithium chloride	red-winged blackbird				15,000 ppm (4 d)	
Magnesium	Japanese quail	1500 ppm (2 wk)	physiol.	1000 ppm (2 wk)		
Mercuric chloride	Japanese quail			2 ppm (1 yr)		
Mercuric chloride	Japanese quail	4 ppm (12 wk)	physiol.	2 ppm		
Mercuric chloride	chicken	100 ppm (8 wk)	reprod.			
Mercuric sulfate	chicken	100 ppm (8 wk)	reprod.			
Methyl mercury chloride	mallard duck			5 ppm (3 mo)		
Methyl mercuty chloride	chicken	5 ppm (8 wk)	reprod.			
Methyl mercury dicyandiamide	mallard duck	0.5 ppm (1 yr)	reprod.			
"	black duck	3 ppm (28 wk/yr, 2 yr)	reprod.			
Monosodium methanearsonate	white-footed mouse	1000 ppm (30 d)	physiol.			300 mg/kg
Octochlorodibenzo-p-dioxin	rat	0.5 mg/kg (2 wk)	pathology	0.1 mg/kg (2 wk)		
PBB (hexabromobiphenyl)	Japanese quail	100 ppm (9 wk)	reprod.	20 ppm (9 wk)		

Selected toxicity data for avian and mammalian wildlife[a]						
Chemical	Species	LOAEL		NOAEL	Acute or Lethal Dose/Conc.[b]	LD_{50} or LC_{50}
		Dose or Conc.[b]	Effect	Dose or Conc.[b]		
PBB (polybrominated biphenyls	mink	1 ppm (10 mo)	reproduction			179 mg/kg 3.95 ppm
PBB	Japanese quail	25 ppm (7 d)	blood chem.			
Sodium arsenite	mallard duck	100 mg/kg (1 d)	thin eggshells			
Sodium cyanide	coyote	4 mg/kg	physiol.			
Sodium monofluoroacetate	mallard duck					3.71 mg/kg
"	mallard duck				9.11 mg/kg	
"	ring-necked pheasant				6.46 mg/kg	
"	chukar partridge				3.51 mg/kg	
"	quail				17.7 mg/kg	
"	pigeon				4.24 mg/kg	
"	house sparrow				3.00 mg/kg	
"	kit fox					0.22 mg/kg
Sodium nitrate	Japanese quail				3300 ppm (7 d)	
Sodium nitrate	Japanese quail				660 ppm (15 wk)	
Thallium sulfate	golden eagle					120 mg/kg
Tribromoethanol	mallard duck				150 mg/kg	

Selected toxicity data for avian and mammalian wildlife[a]						
Chemical	Species	LOAEL		NOAEL	Acute or Lethal Dose/Conc.[b]	LD_{50} or LC_{50}
		Dose or Conc.[b]	Effect	Dose or Conc.[b]		
Vanadyl sulfate	mallard duck	100 ppm (12 wk)	blood chem.	10 ppm (12 wk)		
Zinc phosphide	kit fox					93 mg/kg
Zinc phosphide	red fox				10.64 mg/kg/d (3 d)	
Zinc phosphide	grey fox				8.6 mg/kg/d (3 d)	
Zinc phosphide	great horned owl				22.31 mg/kg/d (3 d)	

[a] Data extracted from TERRE-TOX database (Meyers and Schiller 1986). Complete citations for these data are not yet available.
[b] Dose in mg/kg/day; dietary concentration in ppm; water concentration in mg/L.

APPENDIX B

NOAELs and LOAELs for Laboratory Animals

NOAELs and LOAELs for laboratory animals							
		LOAEL			NOAEL OR NOEL		
Chemical	Species	mg/kg	Concentration in Diet[a] or Water[b]	Effect	mg/kg	Concentration in Diet[a] or Water[b]	References (LOAEL/NOAEL)
Acetone	rat	500 (90 d)		liver and kidney	100 (90 d)		EPA, 1986
Arsenic, inorganic (trivalent) (as As)	mouse		5 mg/L (3 gen.)	decr. litter size			Schroeder and Mitchener, 1971
	rat	4.88	62.5 ppm (2 yr)	decr. growth	2.44	31.3 ppm (2 yr)	Byron et al., 1967
	dog	3.1	125 ppm (2 yr)	decr. survival	1.25	50 ppm (2 yr)	Byron et al., 1967
Barium	rat	5.1 (16 mo)		cardiovascular	0.51 (16 mo)		Perry et al., 1983
Benzene	rat	100 (103 wk)		decr. survival			Huff et al., 1989
	rat	25 (103 wk)		lymphocytopenia			Huff et al., 1989
Beryllium	rat	443 (83 d)		bone; decr. wt	0.54 (1126 d)	5 mg/L (1126 d)	Businco, 1940/Schroeder and Mitchener, 1975
Carbon tetrachloride	rat	10 (12 wk)		liver, necrosis	0.71 (12 wk)		Bruckner et al., 1986
Chlordane	mouse	0.16 (22 d)		blood chem.			TERRE-TOX (78,290,617)

NOAELs and LOAELs for laboratory animals							
		LOAEL			NOAEL OR NOEL		
Chemical	Species	mg/kg	Concentration in Diet[a] or Water[b]	Effect	mg/kg	Concentration in Diet[a] or Water[b]	References (LOAEL/NOAEL)
Chloroform	rat	90 (78 wk)		kidney, testis			Reuber, 1979
Chloroform	dog	12.9 (7.5 yr)		liver, fatty cysts			Heywood et al., 1979
Chromium - Ammonium chromate					2.5 (1 yr)		
Chromium VI	rat				2.4 (2 yr)		Mackenzie et al., 1958
Chromium - Chromic chloride	rat				38.3 (25 wk)		Kurokawa et al., 1985
Chromium - Potassium bichromate	rat				2.5 (1 yr)		Mackenzie et al., 1958
Chromium - Potassium chromate	rat				2.5 (1 yr)		Mackenzie et al., 1958
Chromium - Sodium chromate	rat				2.5 (1 yr)		Mackenzie et al., 1958
Cyanide	rat				10.8 (104 wk)		Howard and Hanzal, 1955
Cyanide	rat	30		decr. wt.; nervous system; thyroid			Philbrick et al., 1979
Cyanide - Chlorine cyanide	rat			whole body; thyroid; nervous system	25.3 (2 yr)		Howard and Hanzal, 1955
Cyanide - Copper cyanide	rat				5 (90 d)		EPA, 1986
Cyanide - Hydrogen cyanide	rat	31		decr. wt; thyroid; nervous system			Philbrick et al., 1979
Cyanide - Hydrogen cyanide	rat				11.2 (2 yr)		Howard and Hanzal, 1955
Cyanide - Potassium cyanide	rat				27 (2 yr)		Howard and Hanzal, 1955

NOAELs and LOAELs for laboratory animals							
		LOAEL			NOAEL OR NOEL		
Chemical	Species	mg/kg	Concentration in Diet[a] or Water[b]	Effect	mg/kg	Concentration in Diet[a] or Water[b]	References (LOAEL/NOAEL)
Cyanide - Potassium silver cyanide	rat				82.7 (2 yr)		Howard and Hanzal, 1955
Cyanide - Silver cyanide	rat				55.7 (2 yr)		Howard and Hanzal, 1955
Cyanide - Sodium cyanide	rat	56 (subchronic)		decr. wt.; thyroid; nervous system	20.4 (CN^-) (104 wk)		Philbrick et al., 1979/Howard and Hanzal, 1955
Cyanide - Zinc cyanide	rat			decr. wt.; thyroid; nervous system	24.3 (2 yr)		Howard and Hanzal, 1955
1,2-Dichloroethane	rat			lung, liver, heart	7.4 (≤8 mo.)		Heppel et al., 1946; Hofman et al., 1971; Spencer et al., 1951
1,1-Dichloroethylene	rat	9 (2 yr)		liver, histol.			Quast et al., 1983
1,2-Dichloroethylene, mixed isomers	rat		500 mg/L	liver lesions			Quast et al., 1983
Ethyl acetate	rat	3600 (90 d)		decr. weight	900 (90 d)		EPA, 1986
Hexachlorocyclohexane	rat		0.9 ppp (90 d)	pathol.			TERRE-TOX (78-290,620)

NOAELs and LOAELs for laboratory animals							
		LOAEL			NOAEL OR NOEL		
Chemical	Species	mg/kg	Concentration in Diet[a] or Water[b]	Effect	mg/kg	Concentration in Diet[a] or Water[b]	References (LOAEL/NOAEL)
Kepone	mouse	12 (10 d gest.)		fetal mortality			TERRE-TOX (76-290,614)
Lead acetate	rat	0.29 (30 d)		testicular damage			Hillerbrand et al., 1973
Managanese	human				0.14		Schroeder et al., 1966
Mercuric chloride	rat	0.64 (39 wk)		immune syst.; kidney			Knoflach et al., 1986
Mercuric sulfide	mouse				13.3		Revis et al., 1989
Mercury, methyl	human	0.2		nervous system			SWG, 1971
Methanol	rat	2500 (90 d)		blood chem.	500 (90 d)		EPA, 1986
Methanol	rat	2.5 (gest.)	0.0002 mg/L	behavior (neonates)			Infurna and Weiss, 1986
Methylene chloride	rat	52.58 (2 yr)		liver, histol.	5.85 (2 yr)		NCA, 1982
Methyl ethyl ketone (inhalation data)	rat				92 (12 wk)		Labelle and Brieger, 1955

NOAELs and LOAELs for laboratory animals							
		LOAEL			NOAEL OR NOEL		
Chemical	Species	mg/kg	Concentration in Diet[a] or Water[b]	Effect	mg/kg	Concentration in Diet[a] or Water[b]	References (LOAEL/NOAEL)
4-Methyl-2-pentanone	rat			liver; kidney	50 (13 wk)		Microbiological Associates, 1986
Nitrate	human	1.8-3.2 (≤ 8 mo)		methemo-globinemia	1.6 (≤ 8 mo)		Bosch et al., 1950
o-Phenylphenol	rat	300 (10 d)					TERRE-TOX (78-290,623)
PCBs (Aroclor 1248)	monkey		2.5 ppm (18 mo)	reprod.			TERRE-TOX (79-290,315)
PCBs (Aroclor 1248)	monkey (young)		0.154 ppm (4 mo)	lethal			TERRE-TOX (79-290,315)
PCBs (Aroclor 1254)	rat	>1.0	>20 ppm (2 gen.)	decr. litter size	<0.25	<5 ppm (2 gen.)	Linder et al., 1974
PCBs (Aroclor 1254)	rabbit			fetotoxicity	10 (gest)		Villeneuve et al., 1971
N-Nitrosodipropylamine	rat		mg/L (30 wk)	lung, inflamm.			Lijinsky and Reuber, 1981a
p-Nitrosodiphenylamine	mouse		4254 ppm (57 wk)	liver			NCI, 1979b
	rat					5000 ppm (long-term)	NCI, 1979b
Strontium (stable)	rat			rachitic changes	263.1 (3 yr)		Skoryna, 1981

NOAELs and LOAELs for laboratory animals							
		LOAEL			NOAEL OR NOEL		
Chemical	Species	mg/kg	Concentration in Diet[a] or Water[b]	Effect	mg/kg	Concentration in Diet[a] or Water[b]	References (LOAEL/NOAEL)
1,1,2,2-Tetrachloroethylene	mouse	300 (78 wk)		liver			NCI, 1977
1,1,2,2-Tetrachloroethylene	mouse	71 (6 wk)		incr. liver wt. and triglycerides	14 (6 wk)		Buben and O'Flaherty, 1985
Toluene	rat	446 (13 wk)		incr. organ wts.	223 (13 wk)		NTP, 1989
1,1,1-Trichloroethane	rat	750 (78 wk)		decr. survival	350 (12 wk)		NCI, 1977/ Bruckner et al., 1985
1,1,1-Trichloroethane	g.pig			liver		500 ppm	Torkelson et al., 1958
Trichloroethylene	rat	150 (2 gen.)		decr. litter size	75		NTP, 1986
Trichloroethylene	mice	300 (2 gen.)		decr. neonate survival	150		NTP, 1985
Uranium (soluble salts)	rabbit	2.8 (30 d)		kidney, histol.			Maynard and Hodge, 1949
Vinyl choride	rat	1.3 (149 wk)		decr. survival; liver	0.13		Dow Chemical Co., 1984

APPENDIX C

List of Common Species of Mammals[C-1] and Birds[C-2] on the Oak Ridge Reservation

C-1. List of common species of mammals found on the Oak Ridge Reservation[a]

Group/Species	Scientific Name	Body Weight (g)	Food Intake	Water Intake	References
<u>Shrews and moles:</u> Short-tailed shrew	*Blarina brevicauda*	14–29; 11	0.49 g/g	0.223 g/g 125 mL/d	Whitaker, 1980 Talmage, 1989
Eastern mole	*Scalopus aquaticus*	82–140			Whitaker, 1980
<u>Rodents:</u> Pine vole	*Microtus pinetorum*	25–39; 20–30		5.5 mL/d; 1.8 mL/d	Whitaker, 1980 ASM, 1969–92 Chew, 1965
Prairie vole	*Microtus ochrogaster*	37–48			Whitaker, 1980
Meadow vole	*Microtus pennsylvanicus*	20–70; 44.2 (avg., m), 44.0 (avg., f)		0.21 mL/g 0.002 mL/d	Whitaker, 1980 ASM, 1969–92 Laughlin et al., 1975
White-footed mouse	*Peromyscus leucopus*	10–43; 22 (avg., TN)		3 mL/d	Whitaker, 1980 Talmage, 1989 Getz, 1968
Golden mouse	*Peromyscus nuttalli*	68–93			Whitaker, 1980
Eastern harvest mouse	*Reithrodontomys humulis*	10–15			Whitaker, 1980
House mouse	*Mus musculus*	18–23			Whitaker, 1980
Cotton rat	*Sigmodon hispidus*	80–120; 110–225 (m) 100–200 (f)		23 mL/d	Whitaker, 1980 ASM, 1969–92

C-1. List of common species of mammals found on the Oak Ridge Reservation[a]

Group/Species	Scientific Name	Body Weight (g)	Food Intake	Water Intake	References
Norway rat	*Rattus norvegicus*	195–485		21 mL/d	Whitaker, 1980 Chew, 1965
Eastern chipmunk	*Tamias striatus*	66–139			Whitaker, 1980
Gray squirrel	*Sciurus carolinensis*	400–710			Whitaker, 1980
Muskrat	*Ondatra zibethica*	541–1,816; 700–1,800			Whitaker, 1980 ASM, 1969-92
<u>Rabbits:</u> Eastern cottontail	*Sylvilagus floridanus*	900–1800; 1134 (avg., m) 1244 (avg., f)			Whitaker, 1980 ASM. 1969-92
<u>Marmotes:</u> Woodchuck	*Marmota monax*	2000–6400			Whitaker, 1980
<u>Marsupials:</u> Opossum	*Didelphis marsupialis*	1800–6300			Whitaker, 1980
<u>Skunks, mink and weasel:</u> Striped skunk	*Mephitis mephitis*	2700–6300			Whitaker, 1980
Mink	*Mustela vison*	700–1600		175 mL/d	Whitaker, 1980 Eriksson et al., 1984
<u>Bats:</u> Red bat	*Lasiurus borealis*	[illegible].5–15			Whitaker, 1980
Big brown bat	*Eptesicus fuscus*	13–18			Whitaker, 1980
<u>Raccoons:</u> Raccoon	*Procyon lotor*	5400–21,600 6170 (avg., m, MI)			Whitaker, 1980 ASM, 1969-92

C-1. List of common species of mammals found on the Oak Ridge Reservation[a]

Group/Species	Scientific Name	Body Weight (g)	Food Intake	Water Intake	References
Fox, coyote, and wolves: Red fox	*Vulpes fulva*	3600–6800			Whitaker, 1980
Gray fox	*Urocyon cineroargenteus*	3300–5900			Whitaker, 1980
Coyote	*Canis latrans*	8000–20,000 (m), 7000–18,000 (f); 16,750 (avg. m, TX) 13,620 (avg., f, TX)			ASM, 1969–92
Red wolf	*Canis fufus*	27,623 (avg, m) 21,591 (avg, f)			ASM, 1969–92
Cats: Bobcat	*Felis rufus*	6400–3100			Whitaker, 1980
Deer: Whitetail deer	*Odocoileus virginianus*	68,000 (avg., m) 45,000 (avg., f)			ASM, 1969–92

C-2. List of common species of birds found on the Oak Ridge Reservation[a]					
Group/Species	Sex	Scientific Name	BW[b] (g)	Food[c] Intake (g/day)	Water[d] Intake (ml/day)
Upland Birds:					
Wild Turkey	F	*Meleagris gallipavo*	4222	148.52	154.86
	M		7400	214.02	225.55
Bobwhite quail	Both	*Colinus virginianus*	178	18.91	18.56
Ruffed grouse	F	*Bonasa umbellus*	532	38.56	38.66
	M		621	42.65	42.88
Mourning dove	F	*Zenaida macroura*	115	14.23	13.85
	M		123	14.86	14.49
Domestic pigeon	Both	*Columba livia*	542	39.03	39.14
Killdeer	F	*Charadrius vociferus*	101	13.07	12.70
	M		92.1	12.31	11.93
American woodcock	F	*Philohela minor*	219	21.64	21.33
	M		176	18.77	18.42
Waterfowl:					
Black duck	F	*Anas rubripes*	1100	61.88	62.89
	M		1400	72.39	73.92
Mallard duck	Both	*Anas platyrhychos*	1082	61.21	62.20
Blue-winged teal	F	*Anas discors*	363	30.07	29.92
	M		409	32.49	32.41
Canadian goose	F	*Branta canadensis*	3314	126.86	131.67
	M		3814	139.01	144.67
American coot	F	*Fulica americana*	560	39.87	40.01
	M		724	47.13	47.52
Wood duck	F	*Aix sponsa*	635	43.27	43.52
	M		681	45.28	45.61

C-2. List of common species of birds found on the Oak Ridge Reservation[a]					
Group/Species	Sex	Scientific Name	BW[b] (g)	Food[c] Intake (g/day)	Water[d] Intake (ml/day)
<u>Wading birds:</u>					
Great blue heron	F	*Ardea herodias*	2204	97.28	100.19
	M		2576	107.67	111.22
Green heron	Both	*Butorides virescens*	212	21.18	20.87
Belted kingfisher	Both	*Ceryle alcyon*	148	16.77	16.40
<u>Raptors:</u>					
American osprey	F	*Pandion haliaetus*	1568	77.94	79.75
	M		1403	72.50	74.03
Red-tailed hawk	F	*Buteo jamaciencis*	1224	66.33	67.56
	M		1028	59.21	60.10
Red-shouldered hawk	F	*Buteo lineatus*	643	43.62	43.89
	M		475	35.82	35.83
Broad-winged hawk	F	*Buteo platypterus*	480	36.06	36.08
	M		420	33.06	32.99
Northern Harrier	F	*Circus cyaneus*	531	38.51	38.61
	M		350	29.36	29.20
Cooper's hawk	F	*Accipiter cooperi*	529	38.42	38.51
	M		349	29.31	29.14
Sharp-shinned hawk	F	*Accipiter striatus*	174	18.63	18.28
	M		103	13.24	12.87
Great horned owl	F	*Bubo virginianus*	1769	84.30	86.46
	M		1318	69.60	70.99
Barred owl	F	*Strix varia*	801	50.33	50.85
	M		632	43.14	43.38
Eastern screech owl	F	*Otus asio*	194	20.00	19.66
	M		167	18.14	17.79

C-2. List of common species of birds found on the Oak Ridge Reservation[a]					
Group/Species	**Sex**	**Scientific Name**	**BW[b] (g)**	**Food[c] Intake (g/day)**	**Water[d] Intake (ml/day)**
Black vulture	F	*Coragyps atratus*	2172	96.35	99.21
	M		1989	90.99	93.53
Turkey vulture	Both	*Cathartes aura*	1467	74.63	76.27
<u>Song birds:</u> Carolina wren	Both	*Thryothorus ludovicianus*	21	5.29	4.43
Carolina chickadee	F	*Parus carolinensis*	9.8	2.77	2.66
	M		10.5	2.94	2.79
Indigo bunting	F	*Passerina cyanea*	14.1	3.77	3.39
	M		14.9	3.95	3.52
Tufted titmouse	Both	*Parus bicolor*	21.6	5.42	4.52
Northern cardinal	F	*Cardinalis cardinalis*	43.9	9.90	7.27
	M		45.4	10.19	7.43
Rufous-sided towhee	F	*Pipilo erthrophthalmus*	39.3	9.02	6.75
	M		41.7	9.48	7.02
Oven bird	Both	*Seiurus autocapillus*	19.4	4.95	4.20
Kentucky warbler	F	*Oporornis formosus*	13.7	3.68	3.33
	M		14.3	3.82	3.43
Hooded warbler	F	*Wilsonia citrina*	10.1	2.84	2.71
	M		10.8	3.01	2.84
Black and white warbler	F	*Mniotilta varia*	10.6	2.96	2.80
	M		11	3.06	2.87
Worm-eating warbler	Both	*Helmitheros vermivorous*	13	3.52	3.22
Northern mockingbird	Both	*Mimus polyglottos*	11	3.06	2.87
Blue jay	Both	*Cyanocitta cristata*	86.6	17.65	11.45
American crow	F	*Corvus brachyrynchos*	438	70.00	33.93
	M		458	72.71	34.96
American robin	Both	*Turdus migratorius*	77.3	16.03	10.61

C-2. List of common species of birds found on the Oak Ridge Reservation[a]					
Group/Species	**Sex**	**Scientific Name**	**BW[b] (g)**	**Food[c] Intake (g/day)**	**Water[d] Intake (ml/day)**
Wood thrush	Both	*Hylocicla mustelina*	47.4	10.58	7.65
European starling	F	*Sturnus vulgaris*	79.9	16.48	10.85
	M		84.7	17.32	11.29
Common grackle	F	*Qusiculus quiscula*	100	19.95	12.61
	M		127	24.44	14.80
Brown-headed cowbird	F	*Molothrus ater*	38.8	8.92	6.69
	M		49.9	11.0	7.92
Song sparrow	F	*Melospiza melodia*	20.5	5.19	4.36
	M		21	5.29	4.43
Field sparrow	Both	*Spizella pusilla*	12.5	3.41	3.13
Chipping sparrow	Both	*Spizella passerina*			
House sparrow	F	*Passer domesticus*	27.4	6.63	5.29
	M		28	6.76	5.37
Red-winged blackbird	F	*Agelaius phoeniceus*	41.5	9.45	7.00
	M		63.6	13.58	9.31
Common Yellowthroat	F	*Geothlypis trichas*	9.9	2.79	2.68
	M		10.3	2.89	2.75
Yellow-breasted chat	F	*Icteria virens*	25.1	6.16	5.00
	M		25.5	6.24	5.05
White-eyed vireo	Both	*Vireo griseus*	11.4	3.15	2.94

[a] Source: Clinch River Breeder Reactor, EIS, 1976-79.
[b] Source: Dunning 1984.
[c] Calculated using Equation 13 (Equation 14 for songbirds).
[d] Calculated using Equation 20.

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